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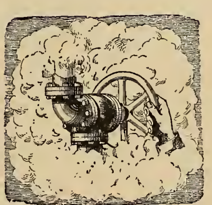

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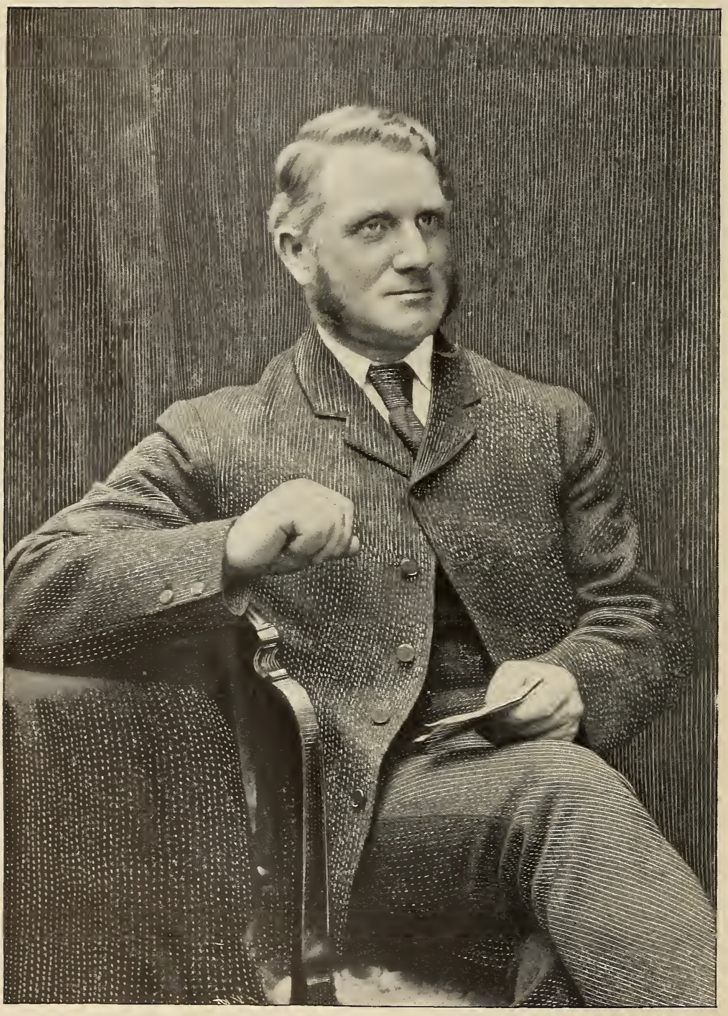


PHOTO BY JOHN FERGUS, CANNES, FRANCE.

William Arrol

CASSIER'S MAGAZINE.

VOL. XV. NOVEMBER, 1898 No. 1

SIR WILLIAM ARROL.

A Biographical Sketch of the Great Bridge Builder.

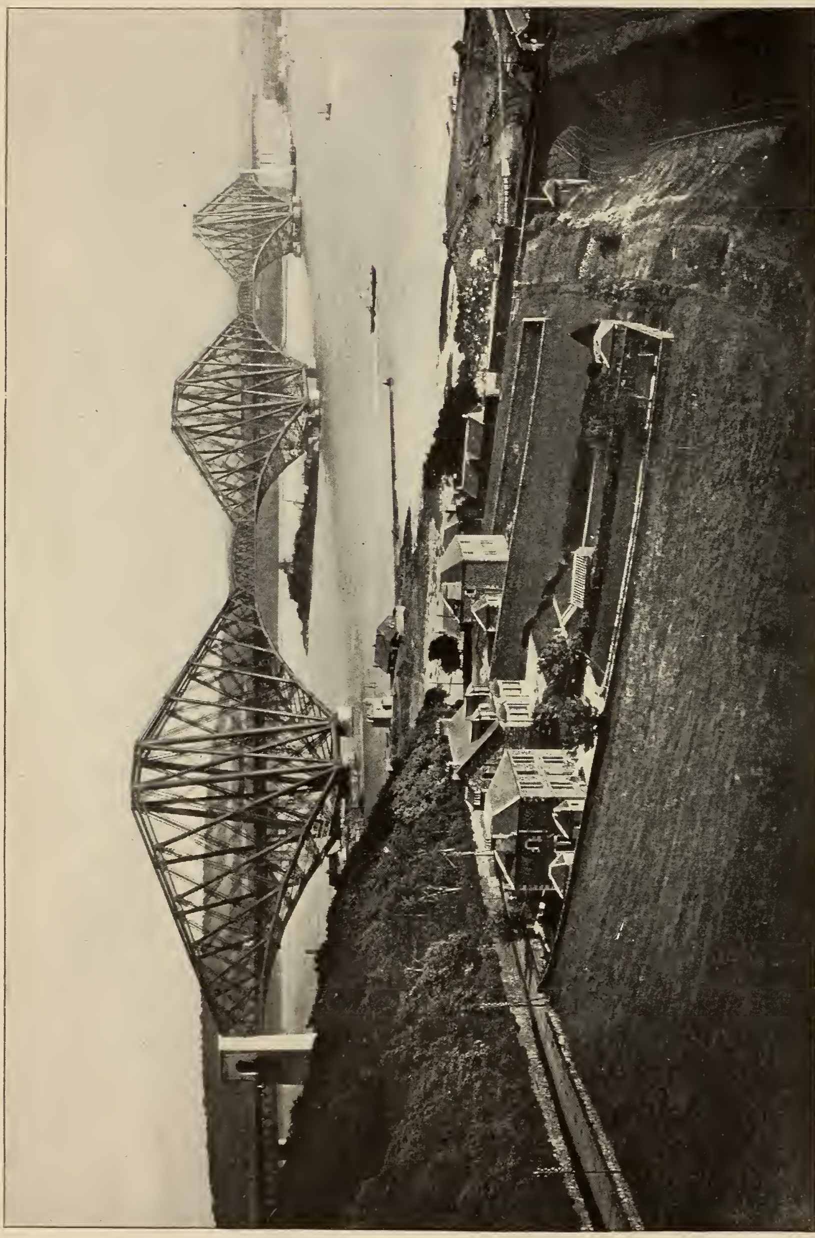
By A. S. Biggart.

THE man endowed with sufficient capacity and energy to develop his own natural abilities lives in the influence he wields over others, and endures in the work he leaves behind him. For such a man difficulties form the training-school in which his powers are developed, and in overcoming them he is inspired with zeal for further achievements. When energy and capacity are combined with a well-balanced mind, and with the bearing that attracts the confidence of his fellow men, he creates enthusiasm in others and inspires them as willing agents in carrying out his undertakings. A man's life is made up of character and conduct, but is moulded by experience, and it is upon the school training of experience that future success or failure mainly depends.

To know Sir William Arrol, and his life and work, is to know such a man, --one who has risen from humble beginnings to the highest position in his profession through sheer ability, and persistent effort. Born in the village of Houston, Renfrewshire, in 1839, he is now in his fifty-ninth year. When he was quite a child his family removed to Johnstone, then, as now, one of the engineering centres of Scotland, where his grandfather was the first to introduce gas. His father, starting as a spinner, raised himself to the position of manager of the great thread works of Messrs. J. & P. Coats, of Paisley.

William Arrol had little schooling, for, at the early age of nine years, he began work as a piecer in a Johnstone cotton-mill. Two years later he entered the bobbin-turning works of Messrs. J. & P. Coats, and at the age of fourteen was apprenticed to a Mr. Reid, a blacksmith and general engineer in Paisley. His apprenticeship over, young Arrol found employment in various districts in England and Scotland, before becoming a foreman in the boiler and bridge yard of Messrs. R. Laidlaw & Sons, of Glasgow. He was then twenty-four years of age, and five years later he began business on his own account within a few hundred yards of the present Dalmarnock Iron Works, in the East End of Glasgow.

He began, of course, in a small way, making boilers, girders, and general



THE FORTH BRIDGE FROM THE NORTH. LENGTH, 8296 FEET. HEIGHT, 354 FEET. SPANS, 1700 FEET.

structural work, and with all the difficulties attending the formation of an entirely new business with small means. Soon, however, the business began to grow, and then grew so rapidly that, in 1871, he was compelled to remove to roomier premises. Then was founded the business which is now carried on by Sir William Arrol & Co., Limited, at the Dalmarnock Iron Works, in the eastern outskirts of Glasgow. In these new and more extensive works Mr. Arrol was enabled to undertake larger contracts than previously in all kinds of structural work, railway bridges, etc. Here also boiler-making for a time was carried on to a considerable extent, but afterwards was set aside in favour of the particular class of work with which the name of Arrol is now associated. With the increasing size and importance of contracts, and consequently greater masses of material requiring to be handled, Mr. Arrol set about designing and making special drilling and riveting plant for the manipulation of material by the most improved and economical methods.

One of the most important contracts at this time was that with the Caledonian Railway Company for a bridge over the Clyde at Bothwell. This structure is a very high one, and Mr. Arrol adopted the novel method of building the bridge on land and rolling it out, span by span, and from pier to pier in front. Another contract was for the ironwork comprising the structural portion of the great Central Station at Carlisle. A larger one still was a contract for the Caledonian Railway Bridge over the Clyde, to carry this railway to the new Central Station. It was to be a large structure, in width sufficient to carry four pairs of rails, and high enough to allow the smaller class of vessels frequenting this portion of the Clyde to pass underneath. It was in connection with the drilling of the booms for the main girders of this bridge that he introduced the system of building these booms complete, passing a traveling drilling machine over them, with the drills in such positions as to make them capable of boring every hole in the entire boom. The depth of drilling in some instances was as much as seven inches of solid material. Not only was special drilling plant made to carry out this contract, but Mr. Arrol, perceiving the great advantage that would be obtained by a system of economical riveting (as the rivets were so large and so long that it was practically impossible to have satisfactory work performed by hand), set about designing plant for the purpose, and the outcome was the introduction of the hydraulic riveting machine, known under the title of Arrol's Patent, which has done so much to revolutionise riveting in the principal bridge-building and ship-building yards of Great Britain.

Important as were these operations, however, they were small compared with the next undertaking to which Mr. Arrol addressed himself, and which was destined to make his reputation and to bring him honour and fame. This was the construction of the great Forth Bridge. When Mr. Arrol first became associated with this great work, the design in hand was that of the late Sir Thomas Bouch, who was the engineer of the first Tay Bridge. Sir Thomas Bouch's plan for spanning the Forth was to throw a suspension bridge over the estuary on the same site as that on which the present bridge stands. This design provided for piers in practically the same positions as the present piers, with this difference, however, that the height of the suspension bridge erections would have been over 600 feet above high-water level. Sir Thomas Bouch's design would have produced a more graceful structure than the present one, but it would not have given the rigidity that is essential where heavy trains are continually passing over at high rates of speed. In the present structure the provision made for resisting wind pressure is much greater than in the original plan. It was, however, on the Bouch design that Mr. Arrol secured the contract for the bridge. He had already spent a large amount of money in preliminary operations, and in the erection of workshops, when suddenly the catastrophe of the fall of the Tay Bridge compelled a pause, and

ultimately the abandonment of the scheme of Sir Thomas Bouch.

After the fall of the Tay Bridge, Mr. Arrol spent some time in examining the old structure and in preparing plans and submitting proposals for rebuilding it. His idea was to surround the old cast iron columns with others of steel, and to connect these new columns securely together by sufficient bracing; but it was found on further examination that the foundations of the old bridge were not so secure as was essential in a structure of this kind. It was, therefore, ultimately decided to discard the

SIR WILLIAM ARROL, AGED 25. FROM A PHOTO BY J. & G. TURNER, GLASGOW.

whole of the old structure and to build an entirely new bridge a short distance further up the river. The new scheme was passed through Parliament, under the guidance and direction of Mr. W. H. Barlow as engineer.

While this was in progress Mr. Arrol was constructing a viaduct over the South-Esk at Montrose, and with a view to gaining experience he adopted the novel method of sinking the cylinders from a pontoon carried by four legs resting on the bottom. The pontoon and legs were so arranged that the pontoon could be lowered, the legs drawn up off the bottom, and the whole floated to a new position, where it was the work of a very short time to drop the legs on the bottom again and raise the pontoon sufficiently clear of the water to allow sinking operations to again commence on the site of any new pier.

When Mr. Arrol's tender for the new Tay viaduct was accepted, he immediately made arrangements for starting the work. His experience with the pontoon at Montrose was such as to decide him to adopt pontoons for the sinking of the cylinders of the new structure. These pontoons were very much larger than that used at Montrose, and contained all the plant necessary for the operations performed at each pier. Thus, the cylinders were built and lowered into position by a hydraulic apparatus from the deck of the pontoon. After the cylinders had been placed in position, the diggers were set to work, these being worked by steam cranes, also resting on the pontoon itself, and when the sinking operations were completed, concrete mixers, having for a platform a part of the pontoon, were employed, and the concrete was filled into the cylinders as required. These various operations being finished, the pontoon was lowered and floated to another pier. The general arrangement of the whole is seen in the illustration on page 16.

Several pontoons were adopted in the building of the new Tay Bridge, and in this work a considerable advantage was gained from the wreckage of the old structure being near at hand, as many of the operations in connection with the new structure were conducted from the old, although the main girders were the only portions of the old bridge actually wrought into the new. These girders were transferred from the old bridge by cranes in the case of the smaller girders, and in the case of the larger girders they were lifted by pontoons bodily off the old bridge and floated and lowered into their final position. A roadway was thus made on

PHOTO BY SIR WILLIAM ARROL & CO., LTD.

SEAFIELD, NEAR AYR, N. B., SIR WILLIAM ARROL'S COUNTRY RESIDENCE.

which the additional new main girders required were run out and lowered.

These arrangements applied only so far as portions of the old structure were used in the new one. In the centre gap of the old bridge from which the main girders fell, and were consequently destroyed, another arrangement had to be adopted. This consisted in floating the girders out from land, and placing them on the new piers at a low level from which they were afterwards raised, span by span, by hydraulic power to their proper position. Temporary columns were used for carrying the weight while they were being raised, and the system adopted was to raise them by hydraulic jacks, resting on girders secured by pins to the columns, step by step, as if one were rising on a ladder. As these girders were raised into position, the iron piers on which they were supported were built underneath, so that when the girders were ultimately at their final level, the weight was transferred from the temporary columns to the main piers. This bridge was begun early in 1882 and completed in June, 1887, and after being most carefully and thoroughly tested by the British Board of Trade, was opened for traffic immediately thereafter.

Not long after the Tay Bridge was begun, Mr. Arrol secured the contract for the Forth Bridge. In this great work the design adopted was that technically known as the cantilever-and-central-span. The cantilevers are supported from main steel piers founded on each bank of the river, with a third, resting on the island of Inchgarvie, equidistant from those on the banks. The cantilever and central girder span is not claimed by the designer, Sir Benjamin Baker, as new in principle, though it is well within the facts of the case to state that no structure approaching the importance of the Forth bridge had been previously constructed on this principle.

The novelty consisted both in the vastness of the structure itself, and in the design of the many and various portions of which it is composed. More-

THE THREE PIERS OF THE FORTH BRIDGE.

over, it was also the first great structure built entirely of mild steel. The two main spans are each 1700 feet clear, and have a headway in the centre 500 feet in length, with not less than 150 feet clear height above high-water mark. These immense spans support exceptional loads to the main piers, and as some of these piers are founded at a depth of almost 90 feet below high water, the making of the foundations alone was a work of exceptional magnitude.

In past engineering practice it has been the habit of engineers to avoid struts of large dimensions, but in this structure a large proportion of the main members are struts of exceptional size and length. They are, in most cases, of tubular form, rigidly stiffened at close intervals, and so satisfactorily was the design worked out that the Board of Trade sanctioned a stress of 7½ tons to the square inch on these members. The main spans of the bridge are approached by viaducts of granite piers and steel girders of an ordinary type, the principal point of interest in connection with them being the great height of the roadway above the water, or ground, level.

Throughout the building of the Forth Bridge Mr. Arrol was the active spirit, and everything was on a gigantic scale. The workshops that had been built for Sir Thomas Bouch's bridge were utilised, and, in addition to these, other large shops were built near the site of the works, for the manipulation of the 60,000 tons of steel required in the structure. The bridge itself was of such a novel type that special plant had to be designed for carrying out the work, and it is in this connection that the impress of Mr. Arrol's personality is seen in practically every stage of the great undertaking.

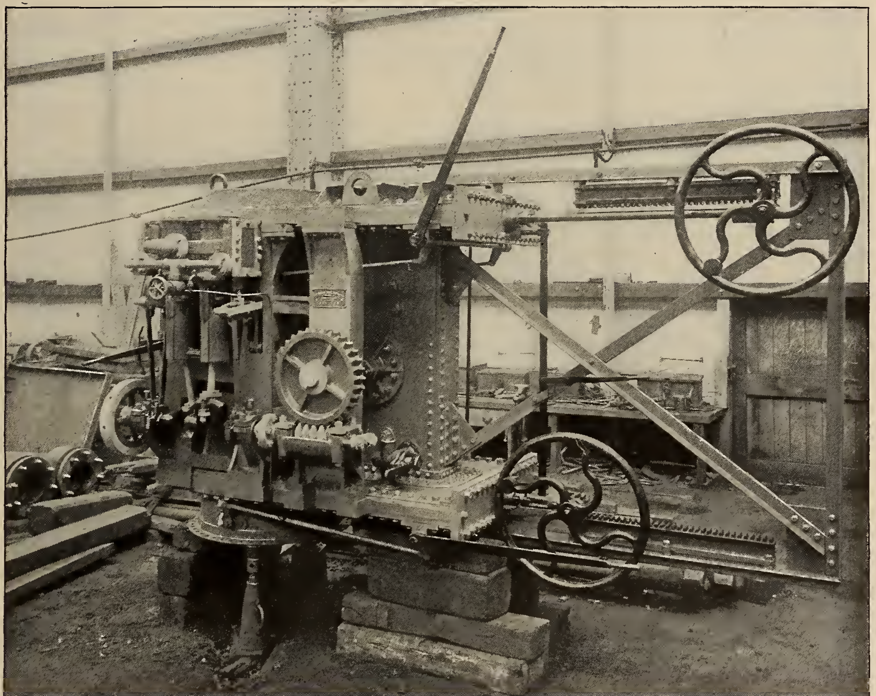
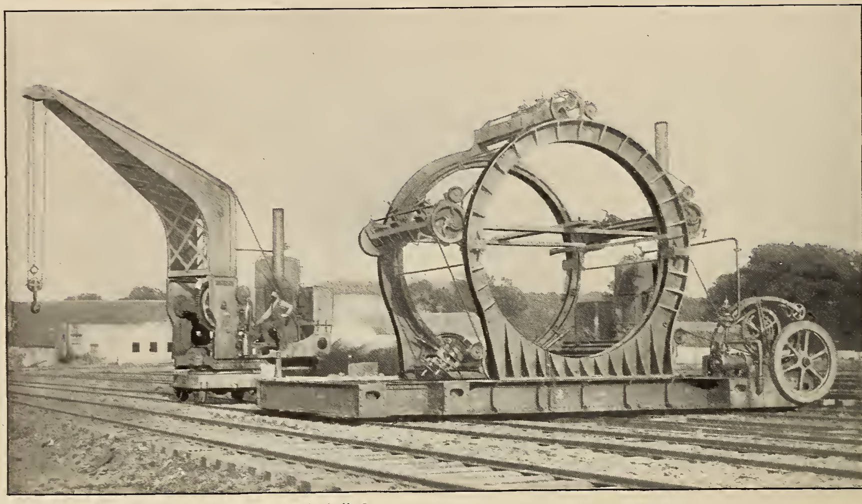


PHOTO BY SIR WILLIAM ARROL & CO., LTD.

THE MATERIAL LOCK USED IN SINKING CYLINDERS WITH COMPRESSED AIR.

In the shops hydraulic power was used to a very great extent, not only for the handling of the material, but



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TRAVELING CRANE AND TUBE-DRILLING MACHINE USED AT THE FORTH BRIDGE.

also, by means of stamping presses, for manipulating it into forms which had not previously been thought possible. All the rivet-holes in the steelwork of the bridge were drilled, and consequently the drilling plant was a very important part of the whole. Mr. Arrol's system of first assembling the parts together and then drilling through the various thicknesses, while placed in the same position as they would occupy when ultimately fixed in the structure itself, was carried out to a very large extent, with the result that the rivet-holes were found, practically speaking, mathematically correct. The traveling drilling machines, which passed over the various parts of the work, were used not only for drilling the main portions of the girders, but also for the many miles of steel tubes required in the structure.

Some idea of the extent of the plant employed may be gained from the fact that it took over a year to have it designed and made ready to begin operations, but even long afterwards large additions were continually being made and applied. It may be of interest to add that the cost of the temporary plant was about £500,000. This included several small steamships, 1,000,000 cubic feet of timber, 1200 tons of service bolts, 60 miles of wire ropes, jacks and rams almost innumerable, and other manifold kinds of machinery and plant in proportion.

During the time the workshops were being got into condition the material for the caissons for the foundations was being prepared by outside contractors. They were then put together on the shores of the Forth. These caissons were all 70 feet in diameter, and after being built and launched sideways, after the fashion of launching a ship, were carried into the waters of the Forth and thereafter floated to the position where they were to be finally sunk into the bed of the river. The sinking of these caissons was one of the novel and most interesting operations in connection with the great structure. After the caissons had been floated over the site they were to occupy, concrete was gradually filled in till there was not only sufficient to sink them to the bed of the river, but also enough to force them into the ground as the material was being excavated in the caisson itself. The caisson proper may be looked upon as a huge diving-bell into which the men descended through air locks and shafts, and as the work of removing the material from the inside proceeds, the caisson lowers itself into the bed of the river. This process was continued till the caisson arrived at its final depth, after which

the concrete and masonry were carried up to their present height.

One of the most ingenious devices called into being by the necessities of the occasion was the hydraulic spade which Mr. Arrol invented for use in the caissons. This consists of a wrought iron cylinder with a brass casting screwed on to one end, through a stuffing face of, say, 15 inches, one man will stand on each side of the spade to lift it by a cross handle and place the point of the spade in the ground, while the third man, stationed behind, opens the cock and allows the water to enter the top, causing an upward movement of the cylinder, which, being arrested, forces the spade into the ground until

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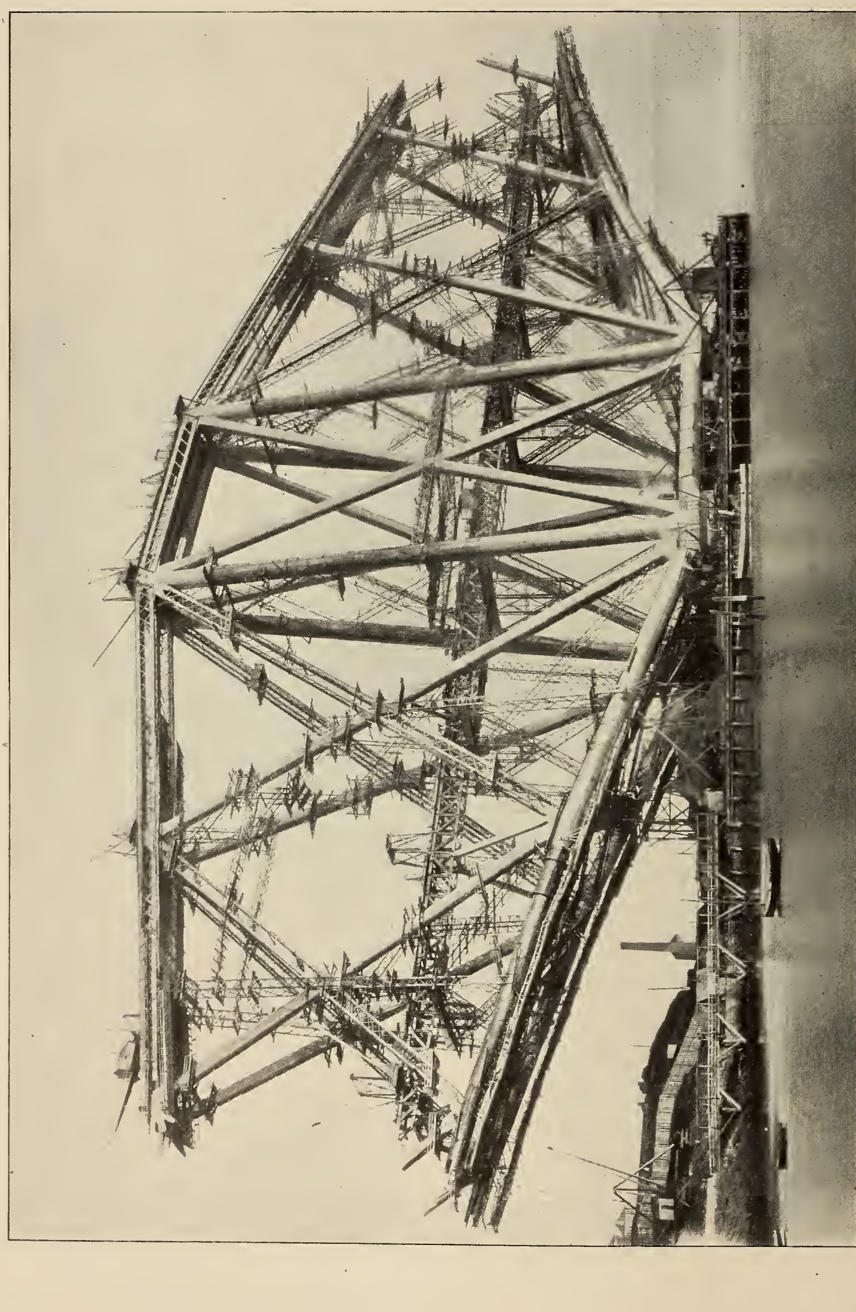
GENERAL VIEW OF THE DRILL ROADS AT THE FORTH BRIDGE.

ing box in which the shaft of the spade passes. On the other end is fixed a cap into which are screwed short wrought iron pipes to vary the lengths of the spade as required. The spade is forged on one end of the shaft, on the other end of which is a piston with the necessary cup leather. A screw in the lower casting communicates with both ends of the cylinder, and high-pressure water is led to it through a small flexible hose, while another hose is employed to carry off the exhaust water.

Each spade is worked by three men, and the action of it is very similar to the ordinary spade. Thus, with a working face of, say, 15 inches, one man will stand on each side of the spade to lift it by a cross handle and place the point of the spade in the ground, while the third man, stationed behind, opens the cock and allows the water to enter the top, causing an upward movement of the cylinder, which, being arrested, forces the spade into the ground until the piston reaches the end of its stroke. Then, upon reversing the cock, the cylinder falls and sets free the upper end, ready to repeat the operation. By means of this ingenious machine material that had before been taken away only piecemeal by hand in the air chambers was now excavated in large lumps.

As the locks for removing the material were of a novel form, an illustration of them is given on page 9. While the main piers in the river were in progress the granite piers for the approaches to the main structure were being built. After these had attained to a level of about 10 feet above high



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THE FIFE MAIN PIER OF THE FORTH BRIDGE.

water, the steel viaducts were built upon them, and were raised by hydraulic power, stage by stage, until they reached their final height of 150 feet above high-water level. As the viaducts were thus raised in stages, the granite piers were built underneath, this operation being so successful that not a hitch occurred during the carrying out of this work. The weight raised in this operation in the case of the longer viaduct was well-nigh 2000 tons of steelwork.

After the main piers had been completed the erection of the superstructure began at three points, namely, North Queensferry, Inchgarvie and South Queensferry. The first portion of the steelwork was one of the most complicated parts in the whole, and is technically known as the skewback. The skewbacks rest immediately over the piers on steel bedplates, and some idea may be formed of their intricacy when it is known that in these skewbacks converge five different tubes and five different sets of wind-bracing in the form of large girders.

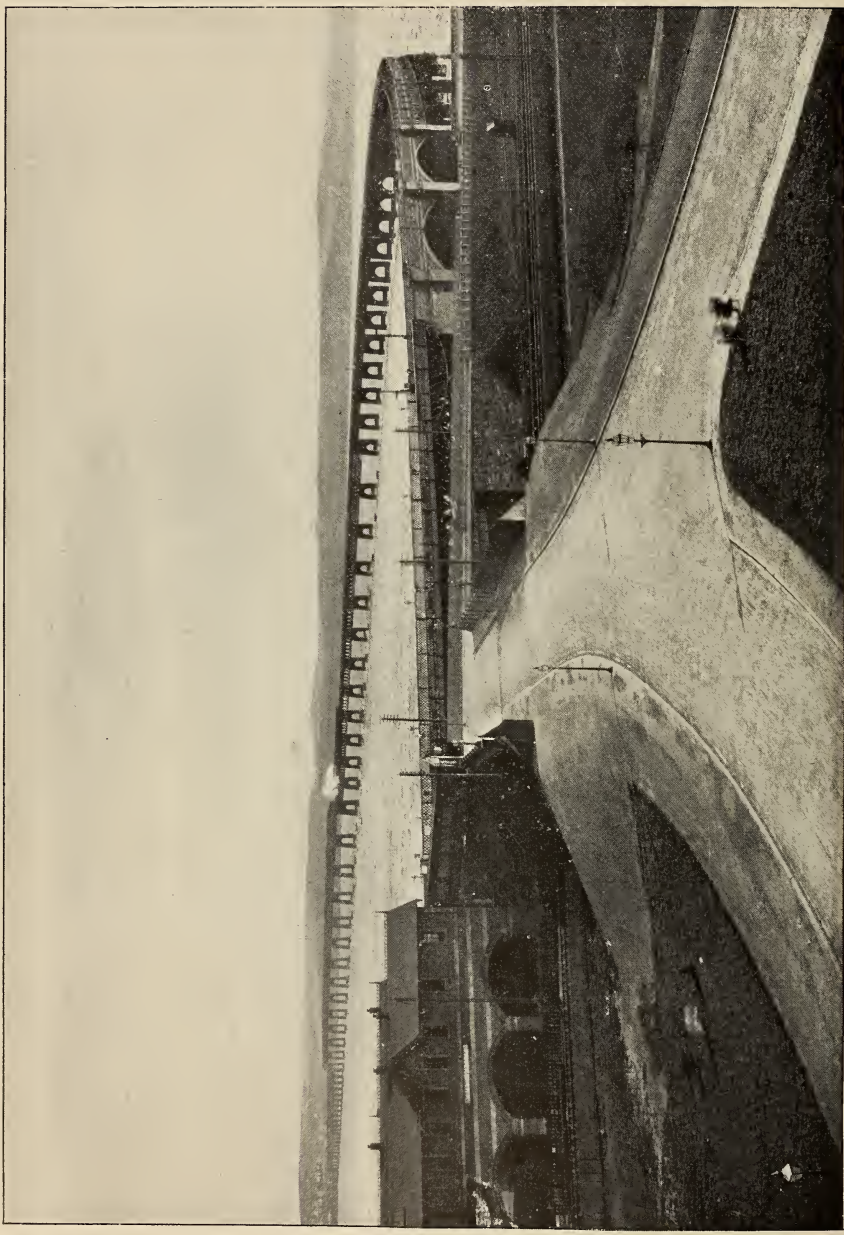
The skewback proper, with its connection to these tubes and girders, although neither very long nor very high, weighs somewhere about 500 tons. While in one sense they are complicated, in another sense they are not, because the design is such that in every hole the rivet intended for it could be put, although in some cases special means had to be taken to effect this. A considerable portion of the riveting in these skewbacks was carried out by small riveting machines, capable of being easily lifted by one hand, but strong enough to withstand a water pressure of from two to three tons per square inch. The smallness of the machine was necessary to allow it to go into the small spaces in the skewback, and it says a great deal for the design, as well as for the system adopted, that every rivet hole was accurately filled by a good rivet as originally intended.

After the skewbacks and the steelwork immediately over the main steel piers had been completed up to a height of about 50 feet, temporary platforms were erected, stretching from column to column in connection with hydraulic lifting arrangements within each of the four vertical steel columns. These platforms were raised in stages from the vertical columns which supported them until they reached the final height of 350 feet above high-water level. As the platform was raised the column was built up, and after the platform reached its final height the upper portions of the structure were built upon the platform itself, until they were completed sufficiently far to enable them to sustain their own weight. While the platform was being raised, these main columns were rivetted by special riveting machines attached underneath.

The riveting machines were of a double character, having a cylinder inside the column as well as one outside. These cylinders were secured to girders running longitudinally with the column, and were raised and lowered by hydraulic power. They had also a circular motion round the column, so that every rivet in the full circumference of the column could be put in by the same power. These machines were so effective that as many as 800 rivets could be driven in a shift of nine hours. The machines were raised with the platform as it rose.

One of the main difficulties in connection with the working of these machines was the supply of steel rivets. Hitherto rivets had either been heated in small hand-blown fires or coal furnaces; but small hand-blown fires could not give the supply of rivets required, and as room for large coal furnaces in a convenient position to the riveting machines was not available, experiments were instituted with a view to adopting oil for the purpose of heating. These experiments were entirely satisfactory, and it was found that a small furnace, 2 feet 6 inches long by 18 inches square, was sufficient to heat easily all the rivets required for the machine. Since then heating rivets by oil has been very largely adopted in the various iron industries.

After the main piers had been carried to their full height, the erection of the cantilevers was immediately taken in



THE NEW TAY VIADUCT AND ESPLANADE STATION.

hand. The first portion of the cantilevers was erected from small overhanging stages by the cranes resting on them. A large platform somewhat similar to that used in the main pier was then adopted, and was raised by somewhat similar means to the level of about 180 feet above high water. These platforms were not carried further, nor were any more of a similar nature used, as it was afterwards found that the work could be much more conveniently carried out from the cranes on the internal viaduct on which the railway now runs, and from those placed on the top member of the superstructure. These cranes, and the small platforms attached to the principals that were being built, offered a more convenient method, which was adopted, for the erection of the remainder of the cantilevers.

After the cantilevers were completed, the next work taken in hand was the erection of the central girders. These were also built by overhanging stages, and special means were taken in connection with joining them up in the centre, so that, when they met, the bottom boom was first connected, and certain of the temporary connections were thereafter relieved, until the top booms were connected and the remaining temporary connections cut away and the girder allowed to rest on the ends of the two adjacent cantilevers.

After the completion of the central girders, little remained to be done to finish the structure for the opening of traffic, and on March 4, 1890, this ceremony was performed by the Prince of Wales. At a banquet which followed the opening, and which was attended by many men of note in the railway world, the Prince of Wales announced that the Queen had been pleased to confer the honour of knighthood upon William Arrol for the great ability he had shown in carrying out this great undertaking.

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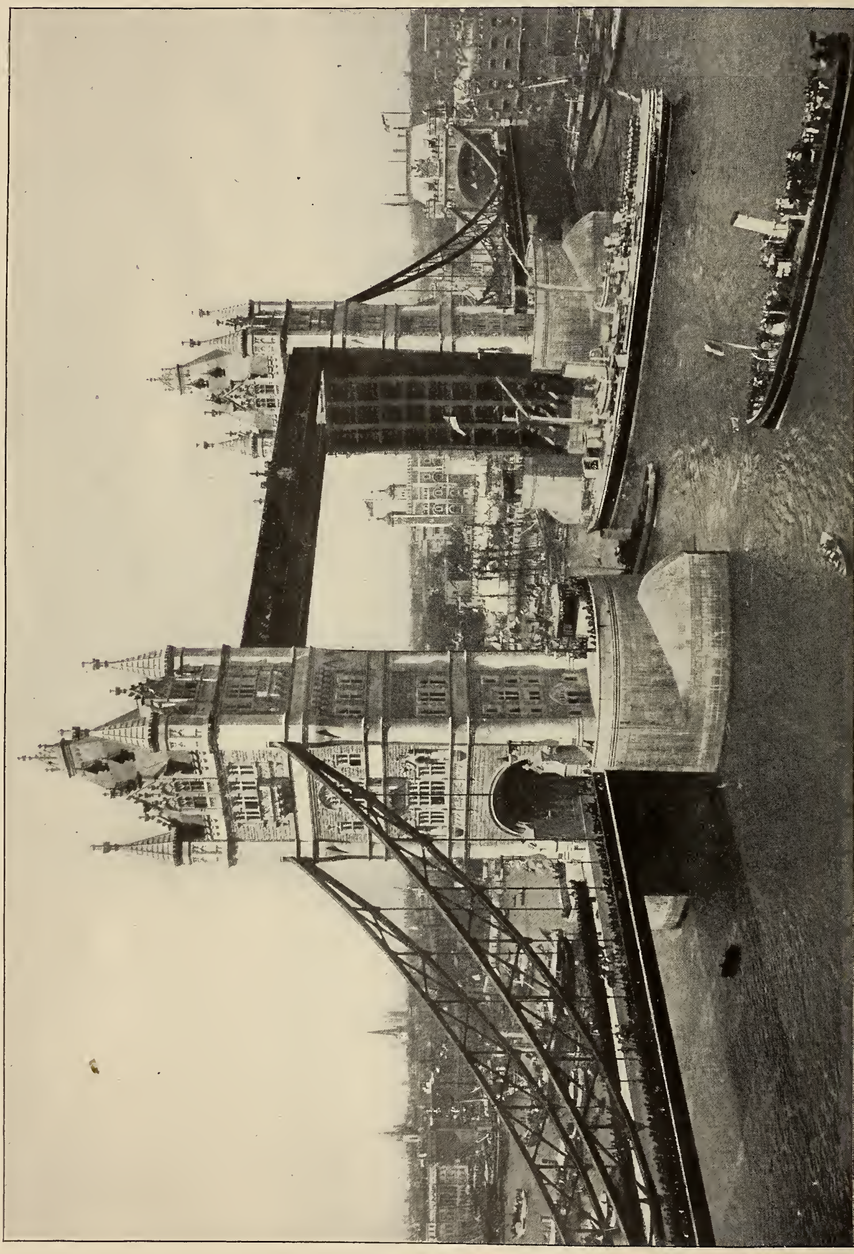
PONTOON FOR SINKING CYLINDERS OF THE NEW TAY VIADUCT.

Shortly before the completion of the Forth Bridge the firm of Sir William Arrol & Co. undertook the erection of all the main viaducts and a good many of the swing bridges for the Manchester



THE TOWER BRIDGE, LONDON, ON THE OPENING DAY, JUNE 30, 1894.

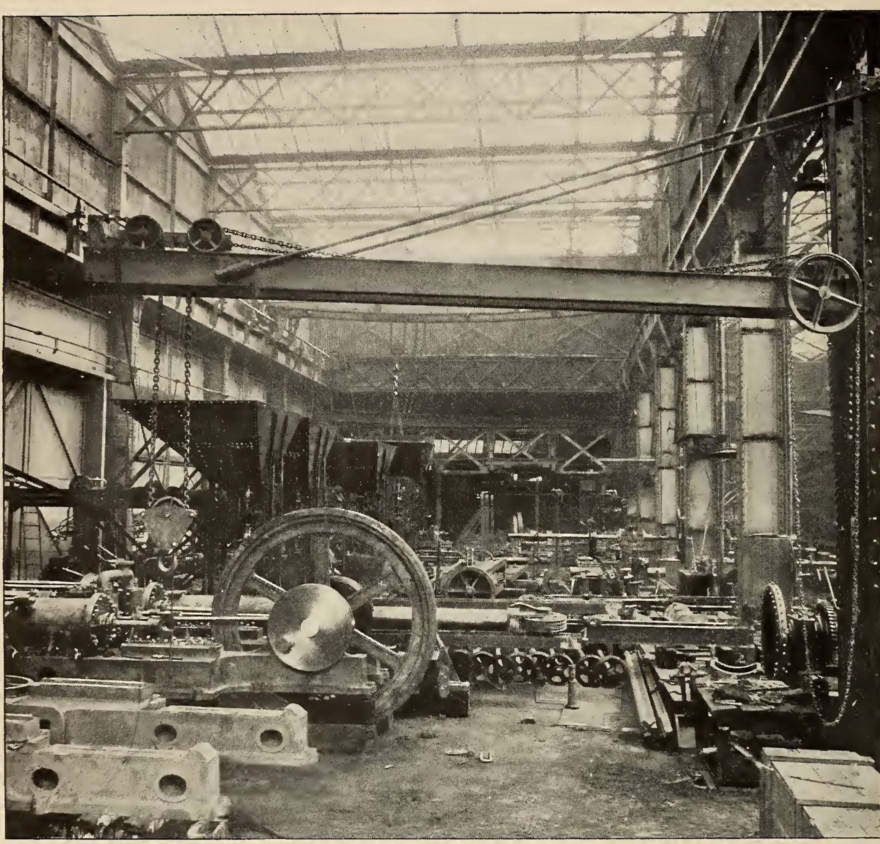
Ship Canal Company. About the same time also they undertook the erection of the steelwork for the Tower Bridge across the Thames in London. This bridge in many respects is one of the most novel in Great Britain, having opening bascule spans in the centre, and a high-level footway overhead to allow of passenger traffic proceeding even while the bascule spans are open.

In the carrying out of this contract it was necessary to stage the River Thames right across, with the exception of the centre opening. The piers were built of steel, with an outside covering of granite. The overhead footway is made up of cantilevers and central girders, and was erected in a manner somewhat similar to that adopted at the Forth Bridge. Before the central girder was joined up, to an observer standing on London Bridge it would seem that the two girders, coming out from the main piers, were at different levels. This, however, was merely an optical delusion, as the central girders met exactly, both as to line and level. After the piers and high-level roadways had been completed, the main chains were erected on a stage, and the approach from the river to the main piers was connected to the chains and completed. The opening ceremony was performed by the Prince of Wales in June, 1894.

PUBLISHED BY PERMISSION OF F. C. COFFIN, ASST. ENGINEER.

THE NEW TAY VIADUCT. PONTOON USED IN TRANSFERRING GIRDERS FROM THE OLD TO THE NEW PIERS.

The firm of Sir William Arrol & Co. do not confine themselves to the work of bridge-building, but carry on a very large general business in mechanical engineering and in all kinds of structural work. They manufacture to a very large extent the riveting machines patented by Sir William, which are adopted in most of the leading shipbuilding and iron centres throughout Great Britain, and also in other countries. In recent years they have also introduced and developed the Arrol-



THE ERECTING SHOP OF SIR WM. ARROL & CO., LTD. THE ROOF IS WHOLLY COVERED BY GLASS.

Foulis stoking plant used in connection with gas works.

This plant consists of machines for charging and withdrawing the retorts after breaking the coal to proper dimensions and raising it to hoppers by elevators from the coal stores, thus reducing the labour bill to a very large extent. In connection with such operations the results have been so successful that the cost of carbonising in many works has been reduced by one shilling per ton of coal handled. When it is mentioned that hundreds of these machines are in operation, and that even under one single management where they are adopted the quantity of coal handled is equal to 600,000 tons per annum, it can at once be seen what an immense saving the adoption of this plant entails. These machines are used very largely not only in Great Britain, among others by the three principal gas companies in London, but also in many of the principal gas works in Europe, Australia and the United States.

In connection with structural work, Sir William Arrol & Co. make a specialty in designing and erecting all kinds of buildings in steel, and one special feature that is always kept in view is the lighting of these, which is usually done by having the roofs entirely covered by glass instead of by slates or other material. The first of these buildings was designed by Sir William about eighteen years ago for the Greenock Foundry Company, in connection with some large extensions which they were making to provide new

machine and fitting shops, and it was so efficient and economical in upkeep that several others have been erected for the same firm, as well as numbers for other firms throughout Great Britain, for engineering works, boiler works, foundries, tanneries, stables, etc.

After the completion of the Forth Bridge the services of Sir William Arrol came into much request in connection with scientific, political and philanthropic work, so that he was compelled to relinquish the active management of his business. By the reconstruction of his firm he secured greater leisure for the growing public calls upon his time.

Sir William was asked to contest the constituency of South Ayrshire, and, in 1895, was elected to Parliament as the representative of one of the largest constituencies in the whole country. This he still represents.

It is not easy for the writer, who was Sir William Arrol's engineer and manager during the construction of the Forth Bridge, and who has been his partner since its completion, to write in any other than an enthusiastic strain of him. To know him in private is to learn to admire his many good qualities. While he is human, and. therefore, fallible, his better side is so genuinely real that it dominates his character. Sir William is, and has always been, a man of the people. He is shrewd, and gifted with sound judgment and good common-sense, and his life work has proved him to be a man of great energy and perseverance. In nature he is most sympathetic and generous, and in him these qualities take a very practical and real form, to the comfort and advantage of many. Perhaps, however, the quality which has most impressed those who know him best is that of tolerance. Many a time has he departed from the strict rules of business to "let off" an unfortunate contractor who was losing on his estimates, and has in some instances even gone the length of making good his loss.

Like all pure-minded men, Sir William is a lover of the beautiful, and gratifies his tastes in this way to a considerable extent. In his house at Seafield, near Ayr, he has gathered a choice collection of pictures and works of art. Although not an ardent politician, Sir William is faithful in attendance to his Parliamentary duties, while at the same time not neglecting the many other calls upon him in connection with his directorship in such companies as J. & P. Coats, Limited; A. & J. Stewart & Menzies, Limited, and others. Not only does he fulfil all these public duties faithfully, but he also finds time to devote to his own business, in which he is always ready to assist with his services and counsel.

With such a range of duties one would think he could not be other than fully occupied; but in addition he takes an active interest in work connected with infirmaries, the Chamber of Commerce, and other public institutions. In Sir William Arrol we find another illustration of the truth of the old adage that "it is the busy man who finds leisure to do the most work." Rest for him and men of his type is best and most efficiently secured by change of occupation. Rich in health and energy, Sir William has the prospect of many years of usefulness still before him, and his friends prescribe no limit to the good he may yet accomplish.

MINE TIMBERING IN THE UNITED STATES.

By John Birkinbine, M. Am. Inst. M. E.

WHEREVER mining is carried on, timber is used as a support to ground which has been disturbed by excavation. The quantity, the size, the character of the wood, and the method of framing or placing the timber are influenced by the abundance or scarcity of convenient forests, the width of the mineral vein matter, lode, or lens to be removed, by the dip of the strata, by the quality of the vein and the adjoining rocks, and other considerations.

In operations prosecuted where the material excavated is such as to safely sustain the roof or walls by pillars, the quantity of mine timber employed may be insignificant, and the application of supports may be confined to single props or stulls. In others, the character of the vein matter or of the inclosing walls, and the length, width or pitch of the deposit of mineral to be won, may demand liberal quantities of mine timber, applied in various methods which add considerably to the cost of mining.

In open-pit excavation timber may be required for other purposes than supports, and in some pits supplemental drifts need to be protected; but as this paper is intended to discuss timbering applied as artificial support to unsafe ground in mining, the comparatively limited employment in the "open" may be dismissed.

In passing, notice should, however, be taken of the liberal application of wood in connection with mining operations independent of that used for support. Below ground the ventilating and drainage systems, the landing platforms, the chutes or winzes, the tramway tracks, sleepers, and the mine cars; and above ground the shaft or head houses, breakers, power houses, trestles, shops, dwellings, sorting platforms, bins, railroads, etc., all demand rough timber or sawn lumber. Ample wood for other uses than support is an essential for mining, and the absence of this may cause mines to lie idle which, under more favourable conditions, would be active.

So important is an ample supply of timber, that the general custom in wording mining leases has been to specify whether or not the lessee will be permitted to cut timber from the lands of the lessor for use in the mine or mines; and the right to thus employ the surface resources for the prosecution of underground operations, is considered a valuable feature in the rentals of many mining properties. An abundance of mine timber so closely influences the success of mining that some large companies buy outright, or purchase "the wood leave" of timber lands, and maintain extensive equipments of machinery and considerable forces of men to fell trees, and cut, frame, and handle the necessary timber.

There are mines, wrought entirely underground, which require but little, if any, timber to sustain the walls or roof, as shown by the illustration on page 22; but even in these there are usually portions of the excavation where artificial supports must be applied, and in this class of workings, shafts or slopes may necessitate heavy and costly framing for protection. On the other hand, even placer deposits which are worked

SOME LARGE TIMBERS.

by "hydraulicking," with water brought in iron pipes, require lumber for the flumes, riffles, and other accessories.

To obtain minerals by underground mining, the productive vein, lode, lens, strata or bed, is reached by a horizontal tunnel or "adit," by an inclined "slope," or by a vertical "shaft," and the material is excavated by connecting the "adit," "slope" or "shaft" with a series of tunnels, or "levels," leading to smaller tunnels or "drifts," or to larger excavations known as "rooms." In a majority of mines the "shafts," "slopes," "adits," "levels," "drifts," and "rooms" must be maintained by artificial supports, for which purpose timber is employed.

Upon the maintenance of these artificial supports depends the lives of those employed, and the permanence of the mine as a producer. It is only where the material to be extracted occurs in quite narrow veins, or where the mineral itself is sufficiently rigid to form safe pillars, or where the walls confining the vein matter are amply stable that the outlay for timbering underground workings and the shafts, slopes, gangways or tunnels leading to them, does not form a prominent item in the cost of mining.

The other extreme is where, practically, every foot of excavation must receive support as work progresses, and these supports require frequent renewal or repeated relief from excessive pressure.

A MINE THAT NEEDS FEW TIMBER SUPPORTS.

The timber requirements, at most mines, demand the constant services of a gang of men above ground, framing, and a gang below ground, placing new, or renewing old, timbers. To facilitate the handling of the sticks required, special timber shafts or slopes and timber chutes are not unusual. Some of the large mines maintain extensive wooded tracts from which the mine timber is cut, and well-equipped mills in which the timber is framed by machinery.

There are several mining operations in the United States which use month-

LIGHT TIMBERS USED IN CAVING SYSTEMS.

ly for mine supports one million or more feet, board measure, of timber. It will, therefore, be evident that the surface forests are being rapidly transferred to form underground forests which sustain the excavations made in prosecuting the mining industry. It is stated that the Comstock group of mines in Nevada consumed the timber from 200,000 acres of forest land up to 1897.

and the table below is presented merely to indicate the extent of the mining industry of the United States. According to the reports of the United States Geological Survey, the following quantities and values of the more important mineral products were taken from the earth during the year 1896. The notes concerning mining are added to indicate the probable dependence upon timber supports :—

Mineral Products of the United States During 1896.

Mineral.	*Quantity or Value*	*Character of Mining.*
Bituminous coal	137,640,276 net tons	Underground.
Anthracite	48,523,287 long tons	Underground.
Iron ore	16,005,499 long tons	Mostly underground.
Building stone	$31,346,171	Quarries.
Petroleum	60,960,361 barrels	Obtained from wells.
Limestone for flux	4,120,102 long tons	Mostly quarried.
Silver	58,834,800 troy ounces	Obtained underground.
Gold	2,568,132 troy ounces	Partially underground, partially in the open.
Copper	460,061,430 pounds	Underground.
Lead	188,000 short tons	Underground.
Zinc	81,499 short tons	Underground.
Gypsum	224,139 short tons.	Mostly quarried.
Cement	9,513,473 barrels	Mostly quarried.
Pyrites	115,483 long tons	Mostly underground.
Salt	13,850,726 barrels	Obtained from wells.

The column with the caption "Character of Mining" indicates the predominant class of exploitation and not the universal practice, for most of the minerals are won partially underground and partially in the open.

It is difficult to even approximate the quantity of timber annually demanded for mine supports from the statement of the amounts of various minerals won,

In addition to the above-named products, a number of others were won and marketed, which required timbering in their exploitation, such as man-

LARGE "STULLS."

A MINE LANDING.

ganese ore, corundum and emery, quicksilver, sulphur, graphite, barytes, and cobalt.

The grand total valuation of mineral products in the United States for the year 1896 was $637,717,288 (£127,-543,457), and probably over 220,000,-000 tons of material were extracted from the earth by underground operations which contributed towards this output. The volume represented by this tonnage would approximate an excavation one square mile in area and 125 feet deep, or a shaft or drift of average size, 7½ × 10 feet, excavated for a length equivalent to the diameter of the earth. The latter comparison will suggest the demands for timber in underground mining in the United States.

The life of timber placed in underground workings is influenced by its character, by moist or dry air, and alterations of the same; and by the tendency of the strata to crush the timber, or to "creep." Unless the wood is brittle, the chances are that excessive pressure, such as would destroy the supports, will give notice in advance of rupture. Therefore, watchfulness on the part of timbermen, or miners, and attention to these indications reduce the risk to life from "squeezes."

There are occasional instances where, notwithstanding liberal supports, large areas which have been mined, cave in. But there are more fatal accidents reported from detached portions of roof or sides falling, or from blasting, than from falling timber supports.

Where the ground in mining operations "creeps" or "swells," the timbers must be reinforced, or the swelling ground repeatedly removed, so as to relieve the pressure. To the uninitiated the extent to which mining ground "creeps" or "swells" without destroying the timber is marvellous, and in some cases those familiar with mining phenomena are astounded that timber withstands compression under enormous loads until its volume is reduced to less than one-half of the original without losing its general structure or entirely destroying its value as a support. In some of the drifts run in the wide veins of the anthracite coal regions of Pennsylvania, swelling ground necessitates constant removal of the excess material. In one instance the "creep" raised the bottom of drifts (which were about 7 feet in height) so that the opening would, practically, close in two days; and measurements of the material removed from the bottom of the drifts so as to keep them open, aggregated a thickness of 45 feet of coal.

A BRICK SUPPORTING ARCH IN THE TILLY FOSTER IRON ORE MINE, NEW YORK.

In some cases the weight upon mine timber compresses it to stone-like hardness, a piece of pine 17 inches in length having been reduced to 4 inches. Yellow pine, taken from the lower levels of the Comstock mines, has been so compacted by enormous pressure as to

A SAMPLE OF GANGWAY TIMBERING.

have the density and weight of lignum vitæ. It has been stated that none of the shafts there are in perfectly good condition, being forced out of line by the rocks moving and swelling. There are, elsewhere, numerous shafts in use which, although originally vertical, are forced into curved or zigzag lines, and slopes could be instanced in which there are very decided "humps."

A feature of mine timbering which demands the best efforts of the engineer is the construction of shafts, or slopes, for these must be planned to last throughout the productive life of the mine. They give access to the workings, are the avenues through which the materials are brought to the surface, and generally supply space for air and waterpipes. The timber framing must, therefore, be of ample strength to sustain the thrust of the strata and be truly fitted for the cages or skips to traverse them at satisfactory speeds, and must be generally reliable as a means for entering or retiring from the mine.

These structures are consequently expensive, and are often costly to maintain. The Lake Superior region in the United States, especially the copper range on the Keweenaw peninsula, of Michigan, presents some excellent examples of this kind of construction. Slopes which exceed one mile in length follow the dip of the copper ore and accommodate skip cars travelling 3000 feet per minute. Two vertical shafts in the district penetrate the earth for nearly 5000 feet, and in these even greater speeds of lift are maintained.

The Red Jacket shaft of the Calumet and Hecla mines has reached a depth of 4900 feet. It is composed of six large compartments, four of which are used for raising rock and lowering timber. Work upon this shaft has been prosecuted for 8 years at a cost approximating $2,500,000 (£500,000). The opening of this shaft is 650 feet above Lake Superior and 1250 feet above ocean level. The bottom of the shaft is, therefore, half a mile below the deepest portion of the bed of Lake Superior, and nearly three-fourths of a mile below the ocean level.

The simplest form of mine support is

a prop or stull, placed between the foot and hanging walls, generally approaching a right angle with the dip, or vertically between the floor and roof of a drift, stope, chamber, or room. As a rule, the top of the prop, or stull, and sometimes the bottom, is supplied with wedges to secure firm support, and with plates made of plank for slabs to augment the surface contact and distribute the crushing force on the end of the stick.

The stulls vary in size from 6 inches in diameter and 6 or 7 feet long, to 3 and 4 feet in diameter and 20 to even 30 feet in length. When the props are of insufficient strength, they are placed in groups or "batteries" and are held together by iron bands. Where local conditions require strong support over a considerable area, "cribbing" is introduced, the timber being laid horizontally and the interior filled with mine refuse. In some of the large mines, cribs of enormous size are employed, requiring the use of great quantities of timber.

Ordinarily mine timbering is considered as made up of "sets" consisting of two props, or legs, whose length approximates the height of the drift or room, and a cap resting on the props, whose length corresponds to the width of the openings. As a rule, the legs are vertical, or nearly so, and the caps and sills, where required, are horizontal. Sometimes one leg of a set is placed at an angle approximating the dip, that on the foot-wall side being nearly vertical and shorter than that on the hanging-wall side, so as to give a horizontal floor to the drift, the cap being also horizontal.

A "SQUARE SET" SYSTEM.

Where the floor is insecure or soft, sills are provided, and on these the props are supported. The sets are located at such intervals as the character of the material requires, and the space

between is protected by small poles, saw-mill slabs, and plank, known as lagging. These sets are also held in place by horizon-braces or "stuttles." Where the ground requires constant support, false sets, supporting fore poles, driven ahead of the permanent sets, are temporarily employed. With firm side walls doubtful roof material may be supported by caps let into the walls, and props are then unnecessary. The lagging extends from cap to cap as when the sets are used.

The tendency of the roof rock to break into an arched form has, in some important mines, encouraged the use of a sill, two legs and segmental caps whose outline approximates to part of an octagon, thus approaching an arch in shape. A noted instance of this is in the Cowenhaven tunnel which pierces the Smuggler Mountain at Aspen, Colorado, for a distance of nearly two miles. This tunnel is 7 feet 8 inches wide at the floor line, and 6 feet 8 inches high in the clear.

"Herring bone" timbering, planned to take advantage of the natural tendency of the loose roof material to form an arch, is arranged with a long round timber placed longitudinally at the top of the drift or tunnel, supported by diagonal props from the sides and covered by lagging. This method, however, requires that the walls be sufficiently firm to sustain the thrust of the props.

Some systems of mine timbering which appear to be intricate, indicate careful study of the requirements and judicious application of the principles of supporting rock or earth with a minimum of timber. One, now much in use, is recognised as the "square set" system or the "Nevada" system, which, while apparently complex, is merely a series of posts, caps, stuttles and sills (sometimes with diagonal

AT THE FOOT OF A SHAFT.

bracing), placed side by side, and above one another, so as to form the outline of a series of adjoining and superposed cubes. Each post, cap, stuttle or sill is framed from a standard to fit snugly, so that when the various parts are assembled and firmly wedged against the walls, openings of considerable height may be filled with a system of practically continuous props, each resting on another below, the width or length being similarly spanned by caps, or stuttles, in continuous lines.

When the walls, roof and floor are kept tightly wedged against a system of "square sets," the weight can be safely carried in openings which are too high, wide, or long, for single sticks which could be handled (even if they were procurable), or for independent series of "sets." Some "square sets" are made of round and some of squared timber, the tenons and corresponding mortices being round or square, according to the preference of the miner. More square than round tenons and mortices are now employed.

By the use of square-set timbering some important mines have been operated which it would have been impracticable to work otherwise. The timbers for square sets are from 5 to 7 feet long, but they are in use in openings whose height, width, or length exceed 100 feet; square-set timber for a room about 100 feet high would be 14 sets or stories in height.

A VIEW IN A DRIFT, SHOWING AN ORE CHUTE.

Whether mine timber should be used with or without bark and whether it should be employed round or squared, are subjects upon which there is a divergence of opinion among mine superintendents. The removal of the bark is somewhat influenced by the character of the wood and the readiness with which the log can be stripped. As the squared timber requires less weight to be handled or shipped, and as it can be framed with exactness more readily than round timber, the distance of the source

TIMBERING IN THE CALUMET AND HECLA MINE.

of supply and the method of timbering adopted often exert influences in its favour.

The foregoing general statements demonstrate that timbering is not only an important, but an expensive feature of mining, and it is to efforts to reduce this cost that many of the improved methods are attributable. The necessity of decreasing the cost of mine timbering is evident, for as mining in any section is prosecuted, the demands upon standing timber are augmented and it becomes requisite to transport it from greater distances. It is seldom that any considerable portion of timber, placed in a mine, can be recovered for subsequent use. Decay, injury due to excessive pressure, damage done in removal, and, more often, the risk attending removal, prevent any appreciable economy in this particular.

The caving system, now quite generally employed, permits timber in smaller amounts and of smaller sizes to be used, in place of larger quantities of greater cross section. The illustration of the caving system shown on page 23 exhibits some of this relatively small timber in place.

Efforts to find substitutes for timber as mine supports have been in the direction of the use of metal props and caps, masonry piers, and concrete arches. These have found limited application in Europe, but in the United States the instances are few.

At the Tilly Foster iron ore mine, in New York, the hard magnetic ore was at first removed by sinking on the ore body from the surface. Subsequently underground exploitation left ore pillars to support the hanging wall, the lens at the 165-foot level being 100 feet wide. These pillars cracked, and slips occurred frequently. Brick arches were then sprung from the foot to the hanging wall across the rooms which had been excavated and these arches were covered with masses of concrete to support the steeply inclined walls and enable the operators to secure the reserves of ore in the pillars and below the levels then wrought.

This plan was but partially successful, and finally the overhanging rock was removed, restoring the mine to an open pit by the quarrying and handling of over 500,000 tons of rock at a cost of $250,000 (£50,000). The illustration

on page 25 shows the brick arches and concrete cover as exposed by the subsequent open cut operations.

At the Calumet and Hecla copper mine, in Michigan, brick partitions and iron doors are used as a protection against fire, and in some European mines masonry shafts are employed.

With the amount of timber required, as above indicated, the possibility of fire in mines will be suggested, and, unfortunately, this has been the cause of great loss, both of life and of money. The relatively small cubical contents of the exploited portion of a mine may be poisoned by the smoke from a cord, or less, of wood, which the strong draughts quickly carry to the workings. In some cases the damage to mine timbers has been insignificant, and yet serious loss of life has resulted. In others, fire from a mine has demanded a stubborn fight, with large expenditures for many months, and great damage to the workings by destroying the supports of questionable grounds.

Considering the recklessness which is noticeable when lighted candles, or lamps with flaming wicks, are hung on props, caps, or lagging, it is remarkable that mine fires are not of more frequent occurrence. Some of the more serious fires have been in mines requiring so little lumber as to cause those engaged in them to feel secure, until a blaze, once started, spread so rapidly through the dry wood as to cut off retreat and cause great loss of life.

PNEUMATIC GRAIN ELEVATORS AND CONVEYORS.

By Fred. E. Duckham, Engineer of the Millwall Docks, London.

IN CASSIER'S MAGAZINE for November, 1897, the article on "Discharging and Storing Grain at British Ports" referred incidentally to the pneumatic elevator invented by the writer. It may be of interest, therefore, to give some further particulars of the pneumatic process as in use for grain handling in Great Britain and on the Continent of Europe.

The grain trade holds a prominent position among the things that have changed during the writer's forty years' connection with docks and shipping. This is attributed partly to free trade and increase of population, but chiefly to the great advances made in steam engineering, in telegraphy, in shipping, and in machinery; for although the population of the United Kingdom increased from 28 millions in 1851 to 35 millions in 1891, enhancing the demand for food, and legislature facilitated the supply of grain from abroad, the importation would be very uncertain and costly if dependent upon the old methods of negotiation, transport and working.

Forty years ago 300 tons of grain were considered a good cargo, and a five months' voyage to the Black Sea and back was a satisfactory performance. The vessels were subject to delays everywhere, by wind and weather, by waiting for orders at ports of call, and by tardy unloading by manual labour during a liberal allowance of lay days.

The change, though slow at first, advanced with increasing rapidity, grain-carrying sailing vessels being replaced by screw steamers, some of 4000 or 5000 tons burden, making the entire voyage to the Black Sea and back within two months, including the time of loading and unloading their cargoes. Some recent cargo steamers for the American trade have, moreover, a dead-weight capacity of from 12,000 to 14,000 tons.

The vessels belonging to the United Kingdom in 1850 had a total tonnage

of $3\frac{1}{2}$ million tons, of which steamships represented 186,474 tons, or 4.8 per cent. In 1897 the total was just 9 million tons, of which $6\frac{1}{3}$ million, or 71 per cent., were in steamers.

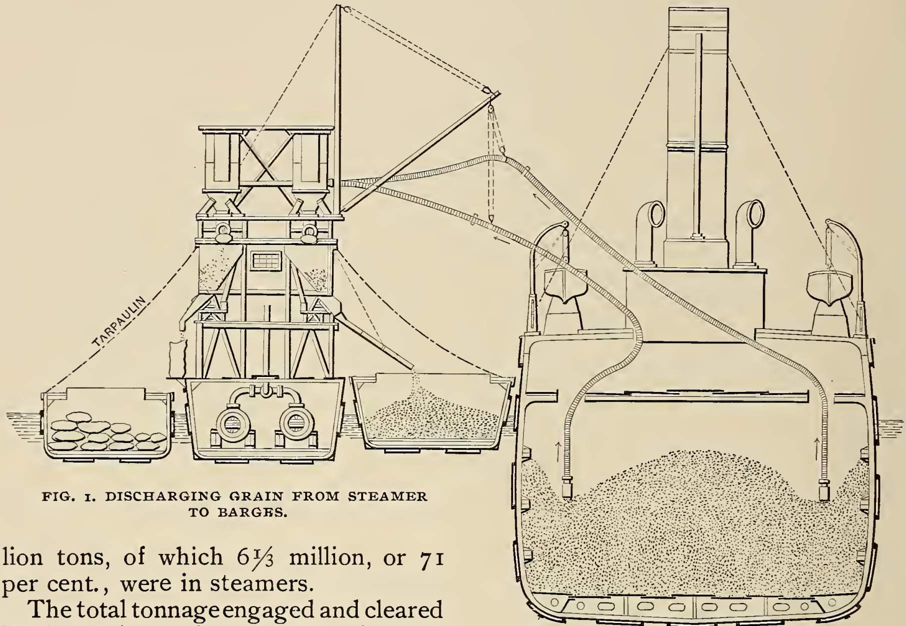


FIG. 1. DISCHARGING GRAIN FROM STEAMER TO BARGES.

The total tonnage engaged and cleared in the United Kingdom ports in 1850 amounted to $14\frac{1}{2}$ million tons, of which 2 1-5 million, or 15 per cent., were steamers, whereas in 1897 the total was 90 million, of which 81 million, or 90 per cent., were steamers.

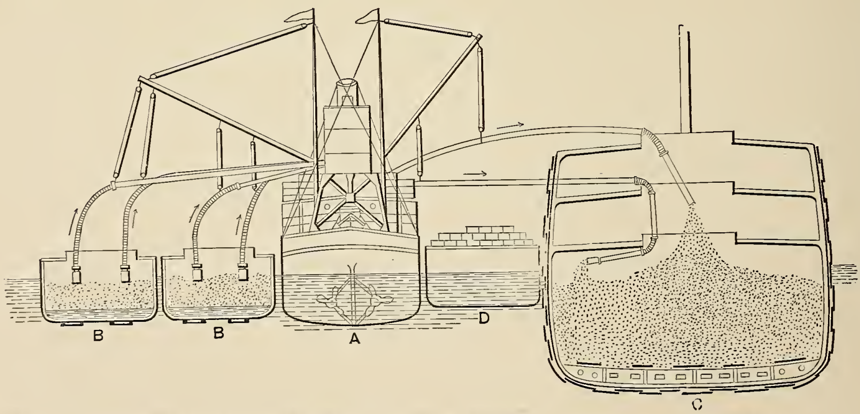


FIG. 2. LOADING GRAIN FROM BARGES *B B* INTO STEAMER *C*, BARGE *D* WITH GENERAL CARGO INTERVENING.

The value of British imports and exports in 1850, moreover, was 192 millions sterling, while in 1897 it reached 745 millions.

During the 10 years ending 1850 the imports of grain averaged 1,022,067 tons per annum; during the 10 years ending 1890 they averaged 6 157,276 tons: while during the year 1896 they reached 9,594,136 tons.

To deal with such increased trade the old methods of manual labour neces-

sarily gave place to various machinery, notably the endless band elevators which have for some years been in use in America and elsewhere: but as the cargoes to be discharged at British ports are often of a mixed character, *e. g.*, general goods and packages in the 'tween decks with grain in bulk in the lower hold, it has been found more convenient to employ hydraulic cranes with buckets or "grabs" for lifting the grain, but admitting at any time of being exchanged for slings or hooks for the discharge of the ordinary merchandise.

With these appliances, however, it is possible to reach only so much of the grain as is within the area of the hatchway. The other portions, which may extend 100 feet or more forward or aft, have to be trimmed to the machine before they can be lifted. Grain is, moreover, frequently stowed in bunkers and other confined spaces whence it could be discharged only by manual labour and sacking.

Labour uncertainties, and the advent of steamers representing a debit of £50 to £80 for each day in port, gave prominence to the necessity for some new appliance that could be relied upon to do the greatest amount of work in the shortest time at the lowest cost with safety.

It was with the foregoing requirements in view that the writer's attention was directed to the employment of air for elevating and conveying bulk grain. There was no originality in this idea. Air under vacuum as well as under pressure had, from time to time, been tried in England and elsewhere, but the several difficulties that presented themselves prevented the successful operation of the machinery. Prominent among these were the impracticability of sucking or forcing grain in bulk through pipes, of getting the grain out of any vacuum chamber into which it had been drawn, and of separating the grain, and, when required, its dust, from the air which had conveyed it.

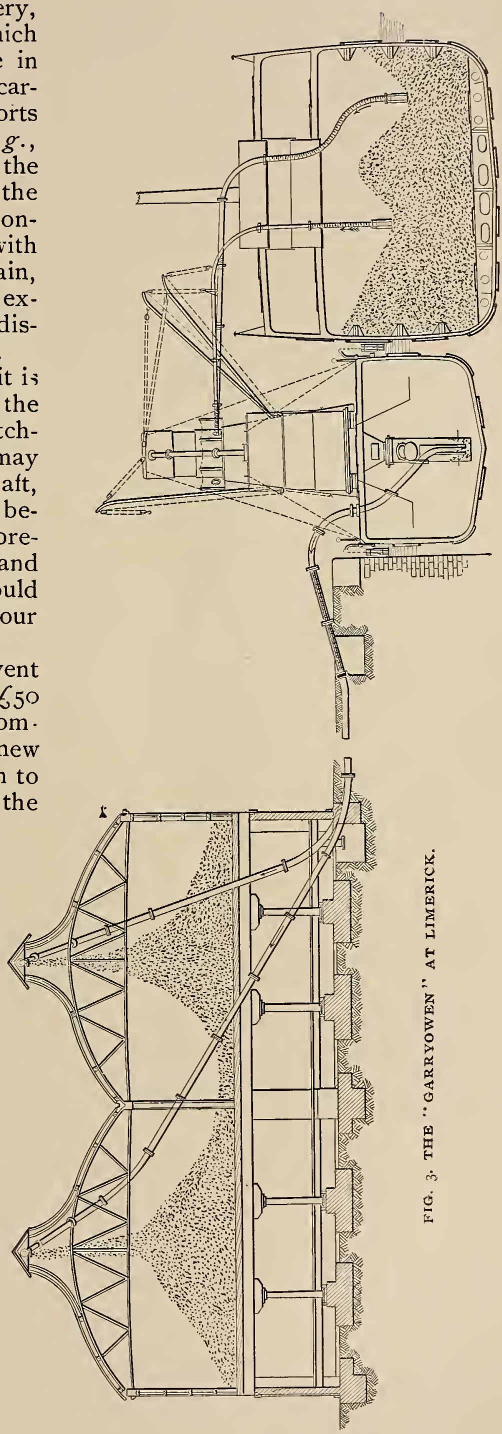


FIG. 3. THE "GARRYOWEN" AT LIMERICK.

There are two types of the writer's

pneumatic elevators now in successful operation:—Those that work by suction set up by partly exhausting the grain-receiving tanks, into which air rushes through semi-flexible pipes from the ship's hold, bringing the grain with it, as shown by Fig. 1, and those that employ air under pressure as well. In these the grain is received by the suction process, but is blown from the elevator into the store or into the receiving ship by compressed air, as shown by Figs. 2 and 3.

A PNEUMATIC GRAIN NOZZLE.

The dominant features of each type are, to begin with, the construction of the inlet nozzles of the grain-conveying pipes in such a way that air, in the correct proportion and speed for each description of grain, may enter the pipe, in doing so pick up the grain, and, by admixture, float it along. It is found that the current of air collects and lifts the grain in a gyratory stream having a speed of 20 or 30 feet per second, and that this touches the pipe only at the ends.

Then there is the so-called armadillo hose, which, though flexible, to enable it to be taken anywhere, is so armoured by steel lining as to resist the wear due to the rapid flow of the grain-laden air.

By means of an automatic air-lock the grain discharges itself from the receiver into which it has been sucked, or finds admission into the chamber from which it is to be expelled. This air-lock consists of a twin box, rocking on trunnions, one side emptying while the other is filling, an air-tight sliding joint being provided between the loading side and the supply.

An important feature of the machinery is the extraction of the grain, and, when required, the dust also, from the conveying air, so that the solid particles are deposited in the receiver and the air is drawn off to the exhauster.

The construction of the outlet nozzle is such that while ordinarily the grain would emerge like a shower from a pea-shooter it may quietly deposit itself where desired,—at any part of the ship or building.

The latest-made machines of each type are represented by the *Chicago*, at the Royal Albert Dock, with her sister, the *Mark Lane No. 2*, at Millwall Dock, London, and the *Garryowen*, at Limerick. The *Chicago* and *Mark Lane* each float on a rectangular hull, 70 feet by 26 feet by 13 feet. The engines, boiler, exhauster pumps, etc., are under deck. At about 'midships there is a tower, about 30 feet high by 20 feet square at

the base, supporting a wrought steel cylinder 14 feet in diameter by 16 feet high, having a double-coned bottom, each cone fitted with one of the automatic air-locks before mentioned.

This cylindrical receiver is exhausted of air to, say, 5 pounds per square inch below the atmosphere. There are externally connections for four 6-inch pipes, made up, partly, of rigid steel tube, and partly of the flexible armadillo hose. These extend from the receiver to the grain, which is usually stowed in the lower hold of the ship. The pipes often reach a length of 200 feet. They are suspended by suitable tackle, and may be swung to the cargo, wherever it may be.

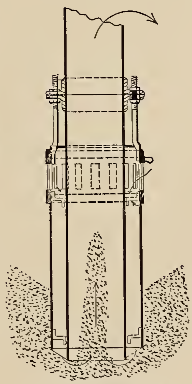
The grain, being drawn up through these powerful suckers, soon finds itself in the cylindrical receiver, makes its way out through the air-lock, and is weighed and delivered in sacks or bulk to the consignee's barges. The *Chicago* has, in ordinary work, transferred 135 tons bulk-wheat per hour from the lower hold of an Atlantic liner into barges alongside. It has been found that the system of delivery by sacks, prevailing to a large extent on the Thames, practically limits the capacity of the elevators to this quantity.

The type represented by the *Garryowen* is illustrated in Fig. 3. This is not only fitted with the just-described suction arrangement for unloading from ships to barges, but is also able to blow the grain into storehouses or into another ship. It, moreover, has the hull and engines of a screw steamer, and often proceeds down the Shannon to partly unload and so reduce the draught of water of grain-laden ships due for Limerick Dock.

The added machinery consists of two compressed-air chambers under deck, into which the stream of grain, after being weighed, may be directed through automatic air-locks, and whence it is expelled by air under pressure of, say, 8 pounds per square inch, through two lines of 8-inch pipes, laid under the wharf and up along the roofs of storehouses. It there deposits itself through suitable outlets. This machine was designed to unload and house 70 tons per hour; but it has dealt with 1030 tons in 10 hours.

The principal advantages of the Duckham system of elevating and conveying grain are:—

1. The pneumatic elevator has no limit in capacity. It is practically independent of everything but its own steam power; it relies upon no operation of being fed by men or machines; its flexible suckers reach the grain wherever it is stowed, and the operation of trimming, which, apart from its cost, vexatiously limits the working power of other ship-discharging elevators, is in this case rendered unnecessary. The working cost on shipboard is thus represented by the wages of one man in attendance at each pipe, the pipe in this case lifting 35 tons per hour.



SECTION OF THE NOZZLE.

2. As previously stated, the large cargo steamers are generally laden with mixed merchandise, *e. g.*, goods in packages in the 'tween decks and grain in the lower hold. Formerly these two kinds of merchandise had to be dealt with in succession, as the elevator and cranes could not work simultaneously in the same hatchway. But the pneumatic suction pipes occupy only a corner of the hatch, and so allow cranes to be employed in discharging the other cargo while they are unobtrusively sucking out thousands of bushels of grain per hour from sundry storage places in the bowels of the big ship.

3. The pneumatic elevator commences operation immediately it gets alongside the ship, and proceeds regardless of weather and light until its work is done.

4. There is an absence of the risks inseparable from ordinary machinery, and in lieu of loss and damage of grain on deck, the grain is aërated and

improved by the process of conveying.

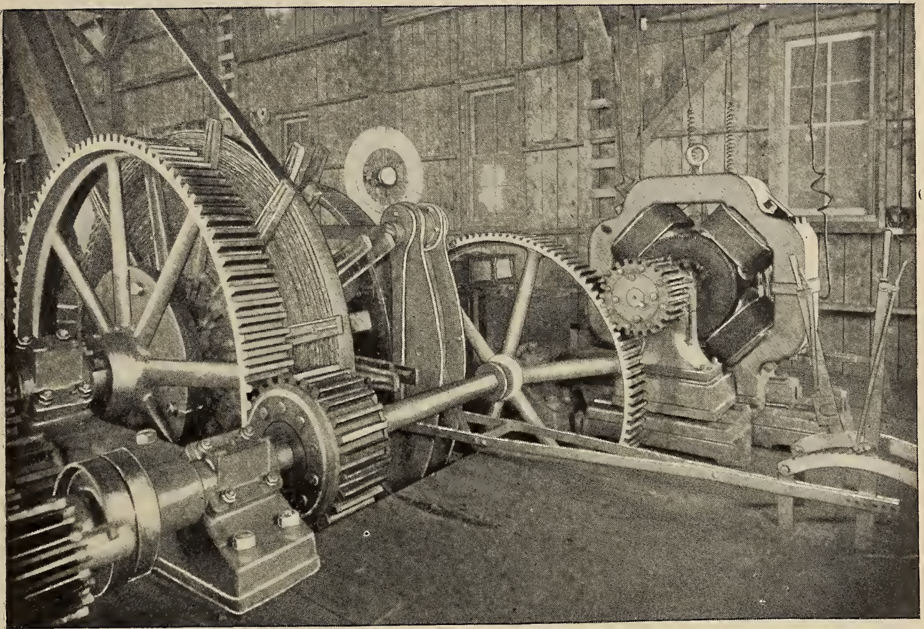
5. Though the initial cost of the steam power is somewhat greater in this than the old-fashioned elevating machinery, the cost of labour is considerably less. This, coupled with the other advantages possessed by the machine, has brought it into favour at several of the European grain ports, and ought to lead to its employment on the American Continent.

Fig. 3 represents a machine intended to transfer 12,000 bushels of wheat per hour from barges into the exporting ship, while lumber and other goods are being shipped at the same hatchway. Its ability to suck grain from all parts of the vessel without the delay of moving the elevator from hatch to hatch is alone a valuable feature. The grain may, moreover, be screened, graded and weighed during the transmission, and may be delivered in sacks or in bulk.

It may be interesting to note that the London Grain Elevator Company, the owners of two of the Duckham machines, last year discharged 17,475,520 bushels of grain, occasionally 250,000 bushels per day, chiefly from steamers laden at United States ports.

ELECTRIC POWER IN MINING.

By John McGhie.

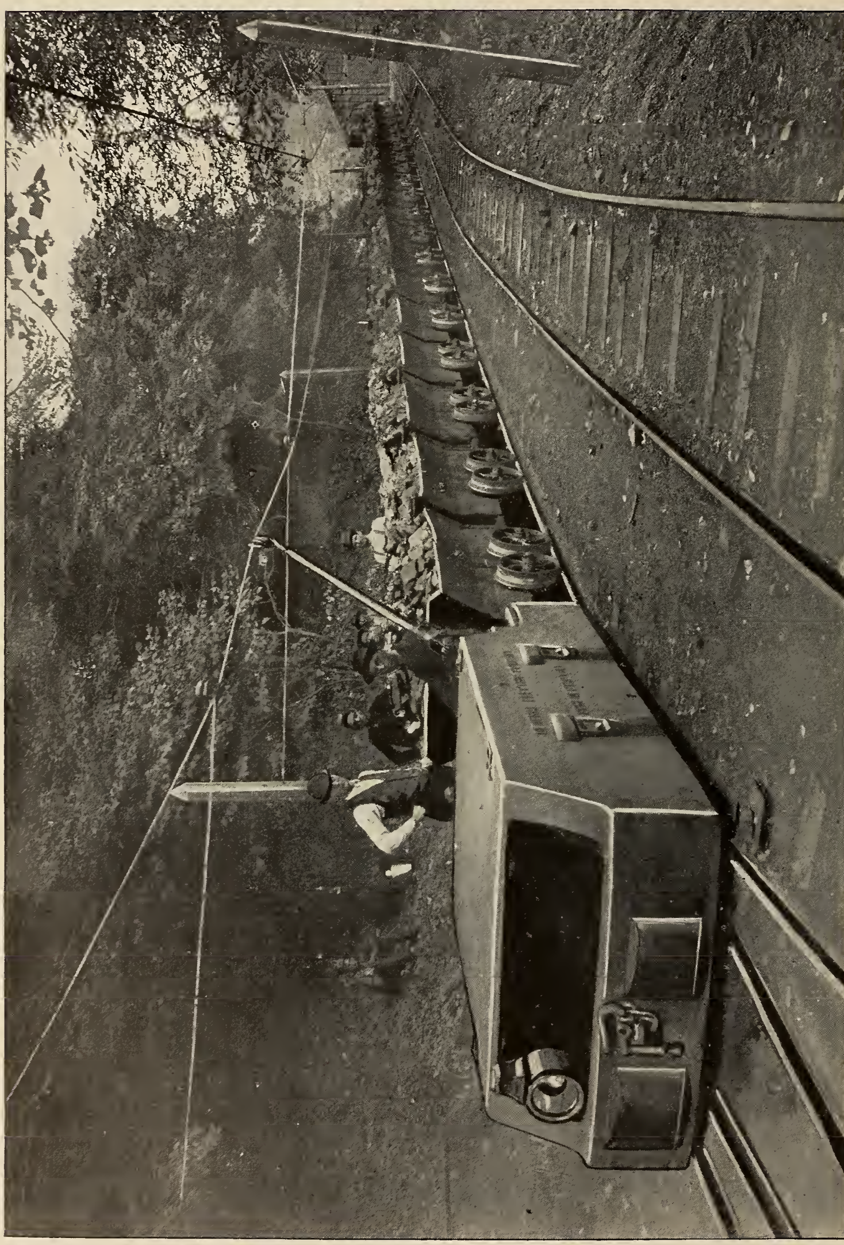


AN ELECTRIC HOIST AT THE FREE SILVER SHAFT, ASPEN, COLORADO.

THE increase in the adaptation of electricity to mining work of all kinds during the past three years has been almost as startling in its rapidity and comprehensiveness as that which marked the earlier years of electric lighting and electric traction. The progress made in these two individual fields on the surface led directly and immediately to the use of electricity in kindred employ in the mine; for what had proved so universally successful in the light of the sun, it was argued, could not prove less so in the depths whither that light never penetrated.

The early attempts, however, were made in trepidation, and to all was not given that measure of immediate success which the sanguine, but somewhat inexperienced, engineer had predicted. Yet, in the majority of cases, economies were realised, difficulties of operation diminished, and sometimes even entirely eliminated, accidents to mines and workers reduced, and such satisfactory results generally were obtained that mine operators and owners no longer turned an unwilling ear to the proposition of the electrical engineer to equip their workings with electrical apparatus.

As in electric railway, motor and lighting work, one mine installation satisfactorily operating proved a living missionary to every other mine operator in the surrounding district. The results obtained, though occasionally jealously guarded, leaked out, and the figures,



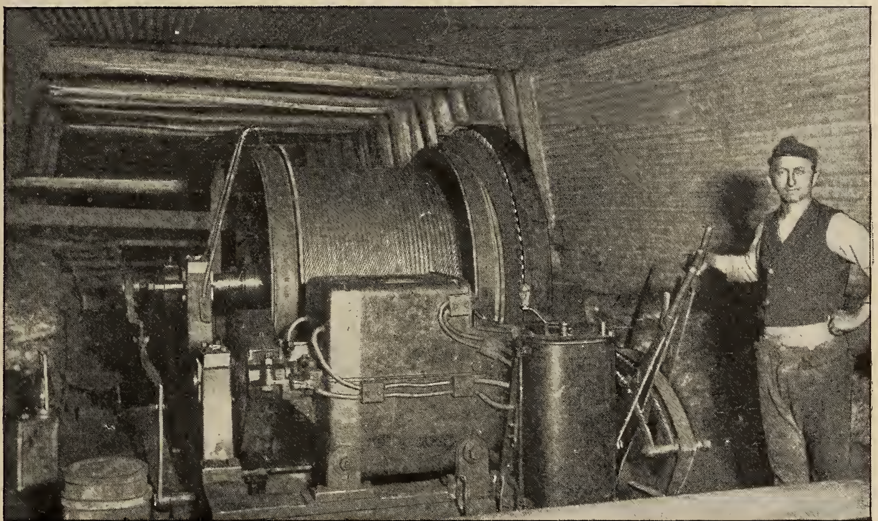
AN ELECTRIC LOCOMOTIVE, BUILT BY THE GENERAL ELECTRIC COMPANY, OF NEW YORK, FOR THE YOUGHIOGHENY RIVER COAL CO., AT SCOTT HAVEN, PA.

finding their way into the columns of the efficient press devoted to the mining industry, gave food for serious reflection to those still dependent altogether on the mule, the steam engine or the air compressor. The question of greater economy, and the consequent greater satisfaction of stockholders, loomed up large and portentous, and as the active propaganda of successful installations became more widespread, its influence became more weighty, the arguments more convincing; and, although conservatism is still strongly entrenched, the eventual equipment with electrical apparatus of all mines, with few exceptions, is now no longer a false prophecy, —it is almost a foregone conclusion.

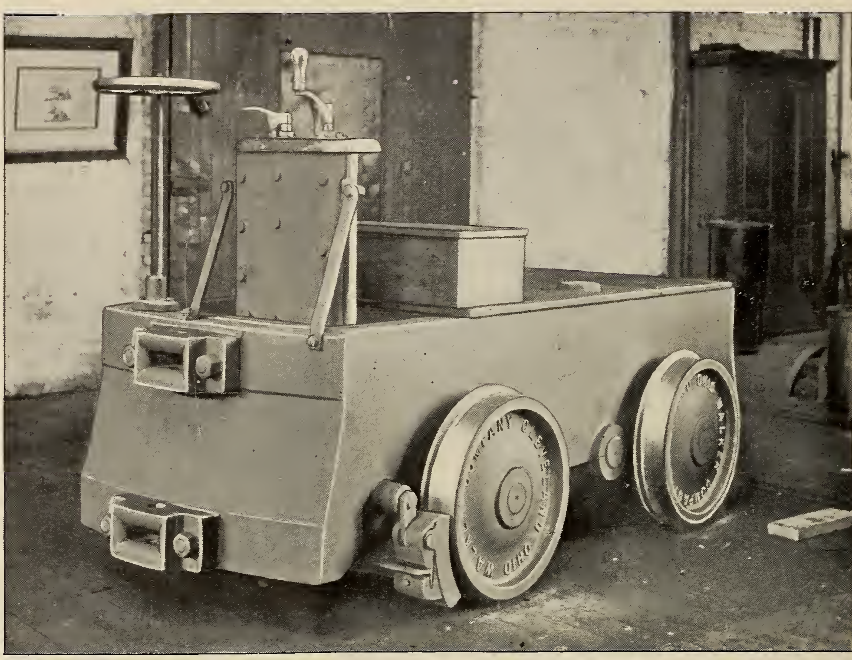
Progress, however, has been, to an extent, hampered by considerations which did not enter largely into street railway and lighting work, but which have played an important rôle in the electric mining field. In the case of electric street railways and electric lighting stations, new industries were to be created, which for capital might appeal to the whole world. There was no question of extinguishing the value of an existing investment.

In arguing electricity into a mine, however, the mine operator has not only had to consider the question of a future benefit, but also what must appear to him the more serious one of a present loss, and it is a known fact that old apparatus assumes in the mind of the owner a factitious value as soon as the question arises of discarding it, and purchasing new apparatus in its place. Furthermore, the change involved not only the supersession of mechanical and animal power in the mine itself; it involved the installation of a complete steam and electrical generating plant at the same time. Electricity, therefore, has been compelled to show that its adaptation to mine work would not only mean future economy, but, also, that its economy would be sufficiently large to compensate for the extinction of the value of the apparatus at present in use. That it has been shown capable of this is, perhaps, best demonstrated by the very large number of mines now using electrical apparatus, and the still larger number in which the use of electricity is proposed and almost decided.

It will hardly be disputed at this date that electricity is the ideal power for use in the operation of mines, and that the advantages it offers, and the benefits



AN ELECTRIC HOIST AT THE MALTBY COLLIERY OF THE LEHIGH VALLEY COAL CO., WILKESBARRE, PA.



AN ELECTRIC MINE LOCOMOTIVE BUILT BY THE WALKER COMPANY, CLEVELAND, OHIO.

which accrue from its use, cannot be equalled or even approached by any other known power, whether animal, steam or air. A power that needs heavy piping; that demands expensive protection in very cold weather and constant expensive maintenance; that cannot be transmitted satisfactorily over long distances; and that operates machinery demanding constant attention, compares poorly with a power that requires two or three slender wires only for its transmission; that gives off no heat, nor smoke, nor moisture; that is unaffected by change in temperature, however severe; that can now be transmitted over long distances, which, five years ago, would have been deemed fabulous; that can be employed indifferently above or below the surface, by day or night, or continuously the twenty-four hours through, and that drives machinery which demands the minimum of attention. And when to these advantageous features are added decided economies in the operation of the workings, cheapening, and, at the same time, increasing the output, while demanding no extensive expenditure for maintenance, the attractiveness of electricity as motive power is irresistible.

There is nothing peculiarly distinctive in the adaptation of electricity to mining work. The problems solved in other fields recur in almost similar shape in the mining field. No new electrical knowledge was required to adapt electricity to the operation of the mine locomotive, mine hoist, mine pump or coal cutter. Mechanical experience and mining knowledge combined speedily applied the motor to the machinery which it was fitted to drive.

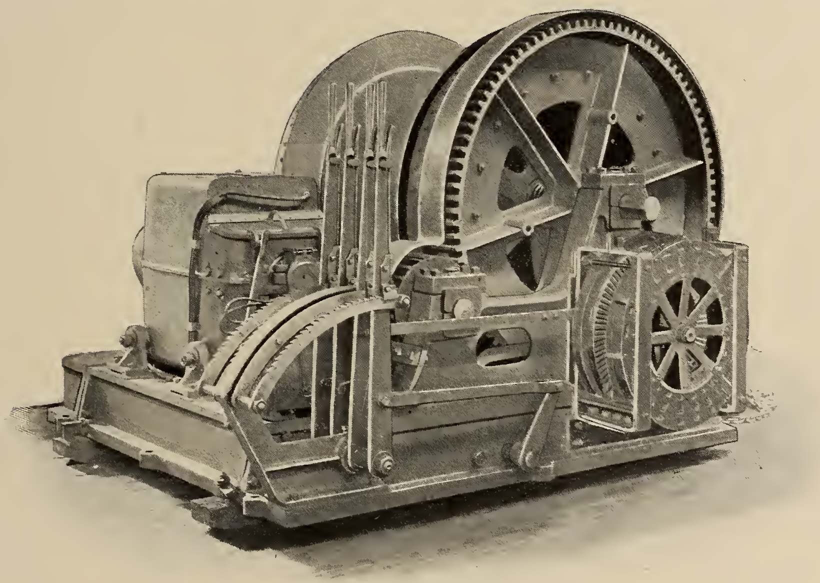
The problem of the economical transmission of electric power to, and in, mines had already found its solution on the surface. Too much mystery is made of electricity in mining work by those gifted with that little knowledge which is admittedly dangerous. There is nothing wonderful about it which the world has not already seen demonstrated everywhere in other industries these ten years past, and to approach to-day the question of an electrical mine equipment with any feeling that electricity is a

mysterious and little-known agent, instead of a useful, fully-known and readily-controlled force, argues more than the usual ineptness.

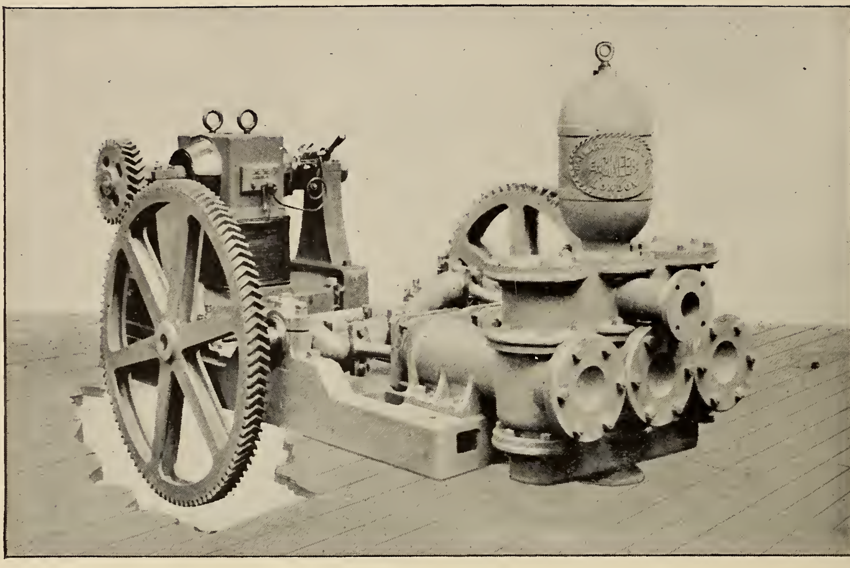
Great progress has, in fact, been made in electrically-operated machinery. Electrical and mechanical components have acted and reacted upon each other, the requirements of the one demanding more perfect workmanship in the other, until the completed device within the past few years has advanced toward a perfection previously inconceived. The electric mine locomotive of to-day bears but slight resemblance to the first one, built almost before the trolley car was an accomplished fact; and the electric mine pump, driven by the early direct-current motor, with cumbersome galvanised iron wire rheostat, is sadly lacking in compactness when compared with the simple induction-motor-driven pump, operated from an extensive three-phase system.

In the design of the electric mine locomotive of to-day every requirement of mine haulage has been considered,—the low roof, the narrow gangway, the weight of the loads and the speed of switching and hauling. The motors are placed as low as possible in as small a space as consistent. They are narrow, to sit snugly in the narrow space between the wheels; they are wound for both power and speed; the motor casing is made water and dust-tight, and the system of control is similar to that which has proved so successful in surface traction.

The advantages of the electric mine pump were clearly perceived from the beginning, and if the mere fact of its extreme portability in the mine had alone been relied upon as an argument, that fact, in itself, would have secured for it the favour of mine operators. With the electric mine pump there is little waste of power in friction and leakage; the space occupied is reduced to a minimum; it may be installed in places not otherwise utilisable; an accident to the conductor can be more readily repaired than one to a steam pipe; the conductors may go down any bore hole in the most convenient way; the cost of maintenance and repairs is



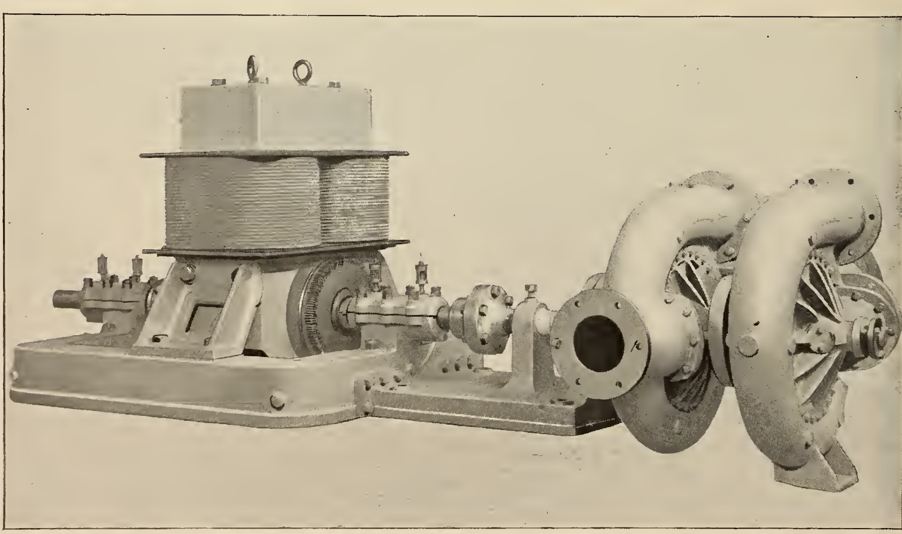
A MINE HOIST MADE BY THE LIDGERWOOD MFG. CO., NEW YORK, EQUIPPED ELECTRICALLY BY THE BRITISH THOMSON-HOUSTON CO., LTD., LONDON.



AN ELECTRIC MINE PUMP BUILT BY MESSRS. HAYWARD-TYLER & CO., LONDON.

small; and the cost of operation, neglecting friction, is proportional to the work done. When the pump is at rest all expense in connection with its operation ceases, and the three-compartment shaft so common in mines, *i. e.*, two for hoisting and one for pumping, can be reduced to a two-compartment shaft, as discharge pipe and conductors can be confined to one of the hoisting compartments.

In addition to the fact that the motor-driven pump can be placed almost anywhere in the mine and its position be rapidly changed when necessary, it can be controlled from any point, near or



AN ELECTRIC CENTRIFUGAL PUMP OUTFIT, MADE BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, ENGLAND.

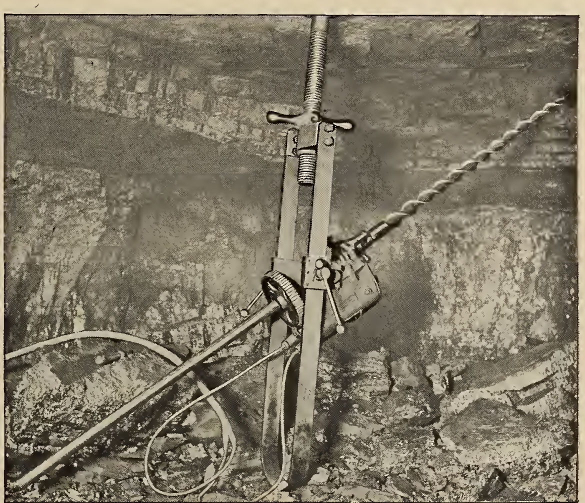
distant, within the workings or on the surface. It requires the service of no skilled operator, and may be started or stopped by the mere closing of a switch, which may be placed even in the office of the engineer himself at the pit mouth.

The adaptation of the motor to the sinking pump has brought into use a singularly compact device, which allows the gearing and operating mechanism to be entirely inclosed in a water-tight steel casing. This type of pump works as readily under, as out of, water. It may be completely drowned by a sudden inrush of water in the mine, but its operation continues, the water exerting only a cooling effect.

The electrically-driven hoist is undoubtedly the most acceptable machine of its class to the miner. It is in the operation of the steam hoist, perhaps, that every drawback of steam-driven machinery in mines may be realised. Standing over the donkey engine, with its exhaust, its rattle, its vibration and its heat, or by the compressed air hoist with every drawback of the steam hoist but the heat, and that changed to extreme cold, the occupation of the operator is one for which there can exist no active competition.

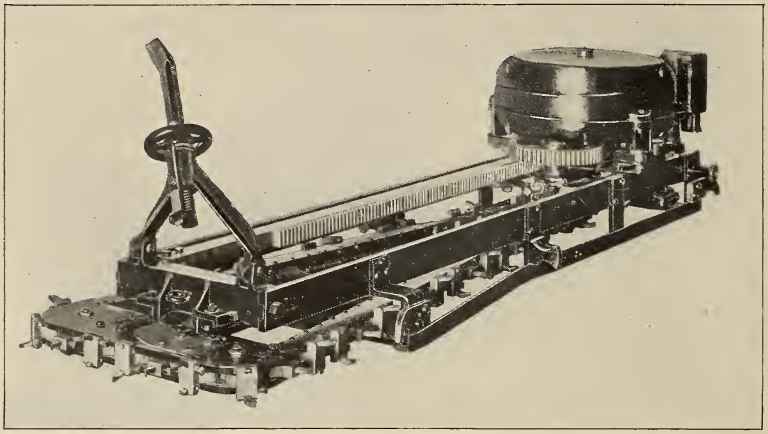
While the electric hoist vibrates, its regular rotary motion cannot be compared to the reciprocating racket of the steam piston rod. It gives off no heat, nor does it create cold. It is under the most perfect control, the speed is constant, and, like other electrical machinery, the power required to drive it is proportional to the load. Like the electric pump, the electric hoist can be located in relation to the incline or shaft exactly where it can be operated to the greatest advantage. These qualities have not been lost on operators, whether of coal or metal mines, and electric mine hoists are now working nearly everywhere.

The Free Silver Mine at Aspen, Col., U. S. A., has probably one of the largest electric hoists in the world. It is a double-reel, flat-rope, over-balanced hoist, with electric power rated at 125 H. P., but capable of exerting 200 horse-power, if necessary. The main motor is a multipolar 100-kilowatt machine, with a speed of 550 revolutions per minute; the auxiliary is a motor of similar type, of 60 kilowatts capacity, and a speed per minute of 475 revolutions. The smaller motor is usually employed to drive an air compressor and a winch for pulling pumps, but is thrown into gear with the main hoist-motor when a heavier load than usual is to be handled.

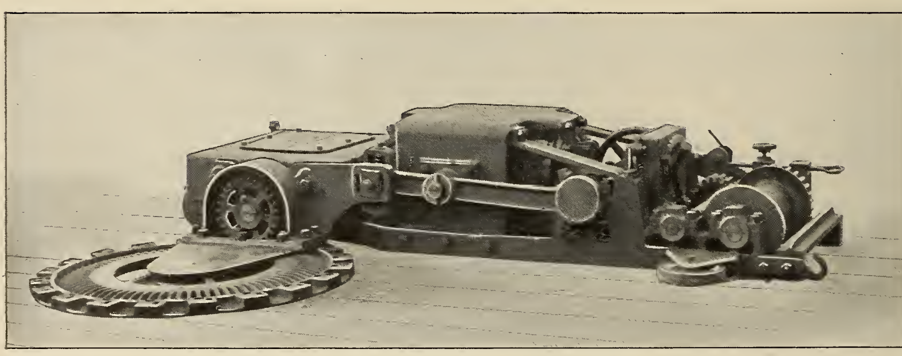


AN ELECTRIC AUGUR DRILL IN THE MINE OF THE LOOKOUT COAL CO., WYOMING, PA.

The hoist being counterbalanced, the load is reduced to about one-third of that which would be thrown on a plain hoist of the same capacity. The radius of the arms of the reels is 5 feet, each reel carrying 1500 feet of rope 4 in. wide and ⅜ in. thick. The hoist has both car and cage, weighing 5000 pounds, and as in sinking the mine it cannot be timbered to the bottom and the cage cannot go below the timbering, a bucket hangs below the cage. This is 35 in. high, 28 in. in diameter, weighs 400 pounds, and holds 12¾ cubic feet of water weighing 800 pounds, or of



A COAL-CUTTING MACHINE DRIVEN BY A THREE-PHASE INDUCTION MOTOR.



AN ELECTRIC LONG-WALL COAL-CUTTING MACHINE MADE BY THE JEFFREY MFG CO., COLUMBUS, O.

rock weighing 2000 pounds. In case of a sudden inflow of water the hoist is provided also with a bailer, used as an adjunct to the pumps. The maximum hoisting speed with cage and car is 600 feet per minute, using the small pinion of the motor; with the bailer and using the large pinion, about 1000 feet per minute. The voltage used is 525, and the current is taken from a central station at Aspen.

In the Alta Argent mine, in the same district, is another hoist. It is placed at the head of the incline, the position being selected as most convenient for the handling of the ore cars. It is placed on a platform 10 feet above the level at the head of the incline where the cars are stopped and run off. At this level, with the hoist above him, the operator stands and handles his controlling levers and switches, unencumbered by the hoist, and giving his attention at the same time to the cars. One man suffices. Had the hoist been placed directly at the head of the incline two men would have been necessary. The hoist is overbalanced, and is driven by a multipolar slow speed 20 H. P. motor, receiving current at 500 volts from the station of the Roaring Fork Electric Light and Power Company 3½ miles distant. The transmission wires pass for two miles above ground and for 1½ miles through a tunnel and mine workings.

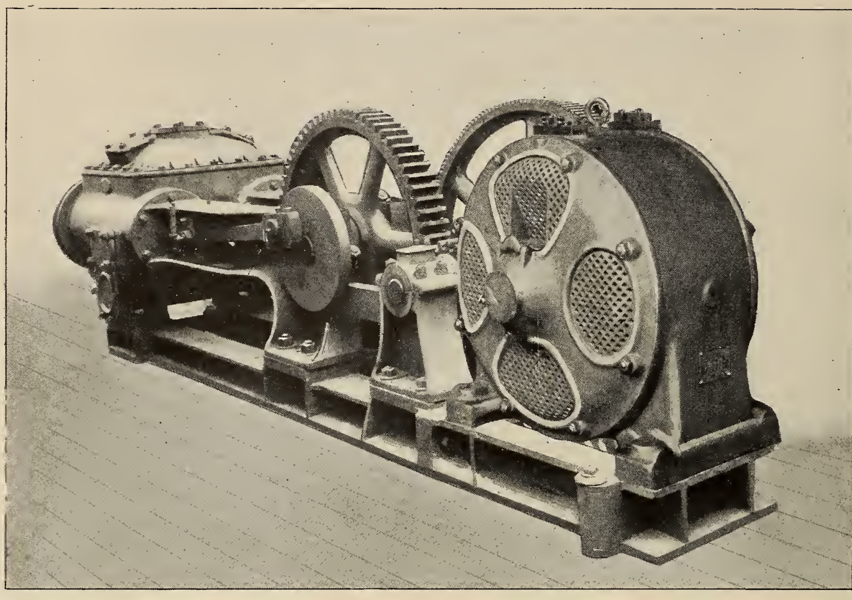
Another example of an electric hoist *in situ* will suffice. This is driven by a

direct-current motor and operates in the Maltby Colliery of the Lehigh Valley Coal Company, at Wilkesbarre, Pa. The hoist is of the single-drum type, designed to lift 5000 pounds at a speed of 500 feet per minute, and is placed also on a platform above the head of the slope; but the operator, in this case, stands behind the hoist on a separate platform. Standing thus he escapes the vibration of the hoist.

The motor is of the 500-volt, railway type, series-wound, and of 110 H P. capacity. It is completely enclosed, and is operated by a rheostatic controller, equipped with a "magnetic blowout," by means of which any sparks are immediately extinguished in a magnetic field. The drum is of the standard friction clutch type, 48 in. in diameter and 38 in. face, holding about 1400 feet of one-inch wire rope. In operation the empty cars are lowered by gravity, overhauling the rope, while the loaded ones are hauled up out of the levels situated at intervals along the slope, the lowest being 1200 feet from the hoist. The usual load is four loaded cars per trip, at an average speed of 500 feet per minute. Each loaded car weighs about three and a half tons, and the hoist is capable, in case of necessity, of hauling six per trip. The cars as they pass over the knuckle of the slope pass on to a parting directly under the hoist.

The introduction of the electric cutting machine into coal mines has materially contributed to the reduction, not, perhaps, in the price of coal to the consumer, but certainly in the cost of production to the operator. Once electricity is brought into the mine, the electric cutter is an almost necessary adjunct to the locomotive, the hoist, and the pump. The economy derived from its use may be summed up in the statement that the percentage of lump from the machine is twenty-five per cent. greater than from hand labour; that the amount of power necessary to shoot down the coal is much smaller,

AN ELECTRIC LOCOMOTIVE BUILT BY THE GENERAL ELECTRIC CO., OF NEW YORK, FOR THE LOOKOUT COAL CO., WYOMING, PA.



PUMP DRIVEN BY AN ALTERNATING CURRENT MOTOR, MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURGH, PA., AND LONDON.

i. e., where an 18-in. cartridge is used to break down hand-picked coal, an 8-in. cartridge suffices when the machine is used to undercut the piece.

The rapidity with which the electric coal cutter can be moved is also noteworthy. It can be shifted from the first position and be ready for the next cut in an average of about two minutes; that is, with the props away from the face and the coal properly squared. When the rooms are adjacent, it can be moved from room to room in about fifteen minutes.

One chain coal cutter will serve as an illustration, as, apart from the motor, the same mechanical features are, more or less, characteristic of all of the chain type. The upper one of the illustrations on page 44 shows a coal cutter driven by a three-phase induction motor laid on its side, with its vertical shaft running at low speed and driving the chain sprocket by a single reduction spur gearing. The motor is completely enclosed, and being of the induction type, with neither commutator, brushes nor moving contacts, and consequently sparkless, it can be used with impunity in gaseous and dusty mines. It stops work when overloaded, and saves the machine from strain and breakage. It reverses and returns automatically as soon as the end of the cutter track is reached. It makes a cut about 4 in. high by 36 in. wide, and in eight hours, in favourable coal, averages eight cuts per hour, or 240 lineal feet in a ten-hour shift. Under the most unfavourable conditions it will average at least four cuts per hour.

Of electric mine drills two types are in use,—the percussion or reciprocating drill and the augur drill. The latter is a simple augur, turned into the ore vein by a small motor. The mechanism is fixed to a stand, which holds it stationary in any fixed position to give the drill the necessary angle.

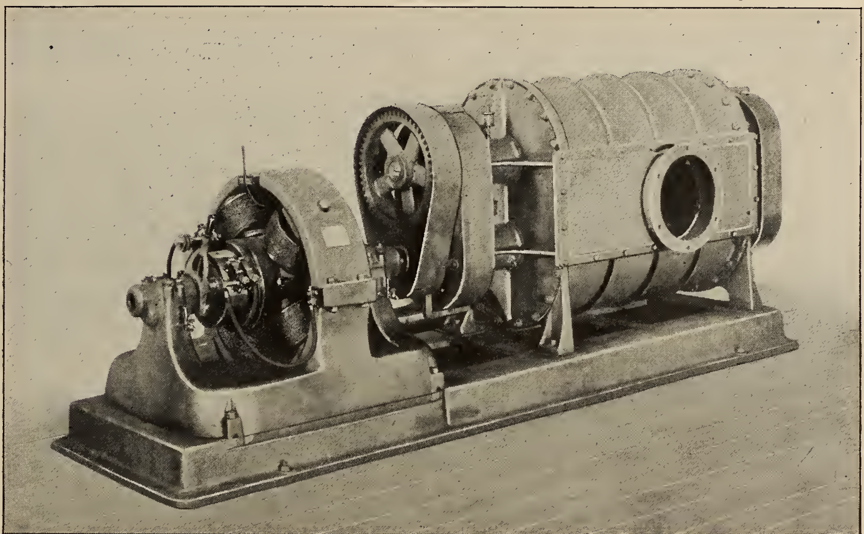
The percussion drill differs from this, both in its operation and its supply. Its mechanism is almost as simple as that of the augur drill, the moving parts having been reduced to a reciprocating steel plunger and a rotating ratchet rod. No electrical knowledge is required to operate the machine. Two coils of wire, alternately energised, raise and

propel the plunger. These are of bare copper wire of square section insulated with mica alone. The stroke may be shortened almost indefinitely, and a hole started even with a ¼-inch stroke, while if the drill is not fed up to the rock and the bit fails to strike, the plunger is automatically cushioned by the coils instead of striking the front head. The drill is stopped and started by the movement of a small handle.

To supply current to the percussion drill demands a special dynamo. This is as simple in construction as the drill itself. It runs at 375 revolutions per minute and delivers current from two copper collars on the shaft to the carbon brushes, each impulse going alternately to the two coils in the drill. The drill operates, consequently, in synchronism, each revolution of the armature producing one full stroke of the drill. The device has obtained a good foothold in quarry as well as in ordinary mine work.

Electric motors are employed also to drive blowers and ventilating fans, sometimes connected together by belt, but generally directly mounted either on the frame or the base of the blower or fan.

Electric machinery has not been introduced into mines without a certain amount of trouble, entirely outside mere missionary work. Conviction has not been obtained without great, and, occasionally expensive, effort. A single example will serve to show this. A prominent manufacturer of electric mine machinery equipped a large freight car with a complete central three-phase station, *i. e.*, with boiler, generator, switchboard and line. This was held ready for installation at the mouth of the mine of any operator desirous of investigating the economy and efficiency of electric mine operation. Station and mine machinery were left with him, and he was thus in a position to watch both generating and operating machinery in comparison with the other methods used in his mine and could judge for himself. The excellent work done by this missionary installation in bringing about a change to newer methods was more than surprising.



AN ELECTRICALLY DRIVEN ROOTS BLOWER FOR MINE SERVICE.

Within the limits of this article it would be impossible to refer to all the different uses to which electricity has been applied directly in mines or indirectly in the allied industries. Electric motors are used to operate dredges and

amalgamators in some of the rich auriferous placer deposits, and to drive the crushers, rolls and stamps of many important mines.

Electricity finds an extensive use in the world's great electrolytic copper works as well as in the phosphate beds of the far South of the United States. It is used to light the galleried workings of cement quarries and to drive coal conveyors and washers at pit mouths. The consideration of these applications, however, must be reserved for some other time.

MECHANICAL DRAUGHT FOR STEAM BOILERS.

By Walter B. Snow.

From a Lecture Delivered at Sibley College, Cornell University.

THE chimney has long stood as practically the only available means of producing draught, which, thus produced, has commonly been called "natural draught," and if it satisfactorily met all of the requirements of modern boiler practice, one would scarcely expect to see a substitute proposed.

Primarily introduced for the purpose of increasing the rate of combustion, artificial draught was designated as "forced draught," its field of application being considered to begin where that of the chimney ended. By later refinements it has, however, become not only a means of assisting chimney draught, and of producing the conditions requisite to accelerated combustion, but it is now accepted as a convenient and efficient substitute for the chimney under all ordinary conditions.

Artificial draught may be produced by means of steam jets inducing a flow of air, by blowing engines, by air compressors, by positive rotary blowers and by fan blowers or exhausters. The fan has been most extensively applied under all conceivable conditions, until it has become the symbol of artificial, or, as it may properly be designated, of mechanical draught, and is to-day the accepted substitute for the chimney.

The centrifugal fan, or fan blower, as an apparatus for producing draught, is no new thing. As applied for the purpose of ventilation it dates back to the sixteenth century, but as a substitute for, or auxiliary to, the chimney, its first application appears to have been made early in the present century by Edwin A. Stevens, of Bordentown, N. J., who, in 1827, arranged a fan for forcing air into the ash pits of the boilers on the steamer *North America.* But engine speeds and steam pressure were then low; the demand for accelerated combustion was not urgent, and experience had not been gained in the proper application of fans for forced draught. As a consequence, this economic improvement, which was to mean so much in later days, was but very meagrely adopted.

It is hardly necessary to here recite the history of the gradual development of this system of draught production. Suffice it to say that at the present day the subject of mechanical draught engages the attention of every progressive engineer in the design of a steam generating plant.

Two types of fans exist. The first,

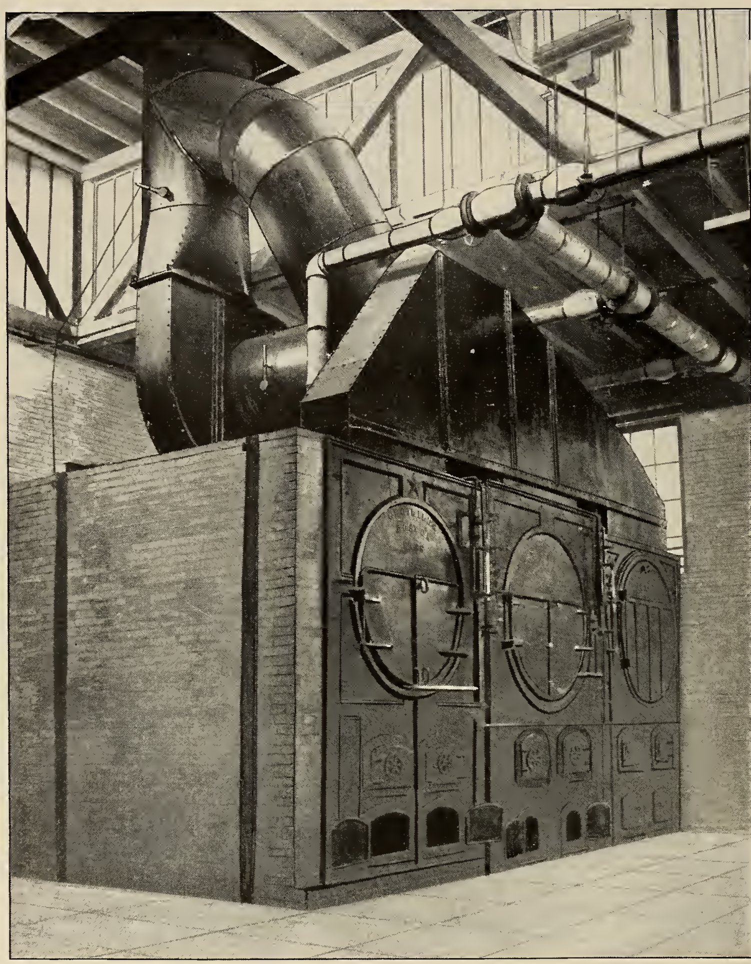
INDUCED-DRAUGHT PLANT WITH STURTEVANT FANS IN THE BOILER HOUSE OF THE HOLYOKE MASS. STREET RAILWAY COMPANY.

known as the disc or propeller wheel, is constructed on the order of the screw propeller and moves the air in lines parallel to its axis. Because of its inability to operate against high pressures, it is practically valueless for draught production. The second, or fan blower proper, consists, in its simplest form, of a number of blades extending radially from the axis, and presenting practically flat surfaces to the air as they revolve. By the action of the wheel the air is drawn in axially at the centre and delivered from the tips of the blades in a tangential direction. This type may be simply designated as the centrifugal fan, or more properly, as the peripheral discharge fan.

The degree of vacuum which may be produced at the inlet, or of pressure which may be maintained at the outlet, of a fan of this type, is dependent upon the circumferential speed of the wheel; and the velocity of the air discharged through an outlet of proper size is substantially equal to that speed.

In the attempt to force air at a given velocity through a given pipe, it is the province of the fan wheel, if employed therefor, to create within the fan case a total pressure above the atmosphere which shall be sufficient to produce the velocity and also overcome the resistances of the case and the pipe. If, however, the pipe be removed and the fan be allowed to discharge the air through a short and properly shaped outlet, the pressure necessary will, with an efficient fan, be substantially that required to produce the velocity.

The pressure created by a given fan varies as the square of its speed; the volume of air delivered is, however, practically constant per revolution, and therefore is directly proportional to the speed.



INDUCED-DRAUGHT PLANT AT THE WORKS OF THE B. F. STURTEVANT CO., JAMAICA PLAIN, MASS.

The work done by a fan in moving air is represented by the distance through which the total pressure is exerted in a given time. It varies as the cube of the velocity; that is, as the cube of the revolutions of the fan. The reason is evident in the fact that the pressure increases as the square of the velocity, while the velocity itself coincidently increases; hence the product of these two factors of the power required is indicated by the cube of the velocity.

A fan should never be made so small that it is necessary to run it above the required pressure in order to deliver the necessary volume. To double the volume under such circumstances requires eight times the power; three times the volume demands twenty-seven times the power.

The chimney as a means of creating a movement of air depends upon the heating of that air, by which a difference in density is produced. The heat thus employed is, however, absolutely wasted so far as its utilisation for any other purpose is concerned. Any attempt to extract more of the heat from the gases as they escape from the boiler must, with a given chimney, result in a

reduction of the draught. This inherent loss with an ordinary coal actually amounts to about 20 per cent. when the gases are at 500° and the excess of air is 100 per cent. Evidently such a great loss as is thus possible should require energetic effort to secure its reduction by means of a more economical substitute for the chimney.

Heat being the agency by which the air movement is brought about, the efficiency of a chimney must be measured by the amount of heat expended for this purpose. As heat is transformable into work, the efficiency is, therefore, to be measured by the number of foot-pounds of work represented by the pressure difference exerted through the distance moved, as compared with the number of foot-pounds represented by the total amount of heat expended.

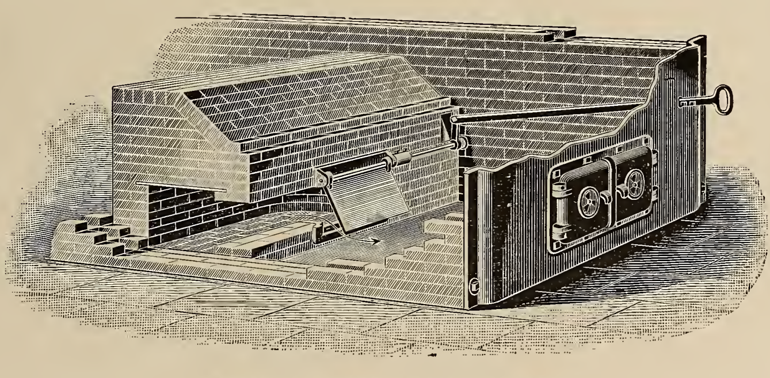
It may be shown that when no work is lost in friction, and the respective temperatures of the external air and the chimney gases are 62° and 500°, the theoretical efficiency of a chimney 100 feet high will be only about six ten-thousandths. In practice the resistance of the chimney, the cooling of the gases and other causes combine to reduce even this extremely low efficiency.

If in the place of the chimney there be substituted an engine-driven fan of proper size, the resultant of the efficiencies of the steam boiler, the engine, and the fan, together with the loss of friction in the apparatus, may be reasonably taken at about 4 per cent. Therefore, the work done, or its equivalent in heat units expended to produce the given result, will be about 70 times as great in the case of a chimney as in that of a fan.

All other questions aside, the fan is, therefore, far more economical than the chimney. This economy means that when a fan is employed, the surplus heat can be utilised and the gases reduced to a minimum temperature before they escape, without impairing the draught.

The methods of application of mechanical draught may be broadly classified under two heads,—the plenum and the vacuum methods. Under the plenum, or "forced," draught, method the air may be supplied in either of two ways. First, by making the ashpit practically airtight, and forcing the air into it. Second, by making the fire room itself practically airtight and maintaining therein the required air pressure.

Under the vacuum or "induced" method there is practically only one means of application,—the introduction of an exhausting fan in the place of a chimney. A short and comparatively light stack usually serves to carry these gases sufficiently high to permit of their harmless escape to the atmosphere.



AN ASHPIT DAMPER IN A BRIDGE WALL.

Evidently, the method of application to be adopted must depend upon circumstances. It cannot be said that under all conditions any one of these three principal methods, or their numerous modifications, is superior to the others.

The application of mechanical

draught presents a three-fold opportunity for increased economy in steam production. First, in the reduction of avoidable losses; second, in a decrease in the first cost and resultant fixed charges on the entire generating plant; and third, in a reduction in the operating expenses, principal among which is the cost of the fuel. In addition, mechanical draught possesses certain advantages which cannot be directly measured in money values, such as its peculiar adaptability to the requirements, its independence of climatic conditions, its flexibility and the like.

A resultant efficiency of 100 per cent. on the part of either the coal or the boiler is an absolute impossibility because of certain inevitable losses incident to the combustion of the coal and the operation of the boiler. Although under the best conditions over 80 per cent. of the full calorific value of the fuel may be utilised in the production of steam, yet, it is true that this high standard is seldom reached in ordinary practice. An efficiency of only 60 per cent. is common practice, and even 50 per cent. is far from exceptionally low.

The losses which are more or less avoidable are:—First, those due to incomplete combustion, as usually evidenced in the presence of smoke and carbonic oxide in the flue gases and in unconsumed coal in the ashes, as well as to a small amount of hydrogen or marsh gas which may pass out with the gases.

Second, loss from excess of air, due to the fact that to secure practically perfect combustion, air is usually supplied in excess of the theoretical quantity chemically required for combustion. This loss is twofold, being dependent upon the quantity of unused oxygen and associated nitrogen and upon the moisture in the air.

Third, the loss resulting from too high temperature of the gases leaving the boiler. This loss, except in so far as it is influenced by the air supply and the rate of combustion, is dependent upon the design of the boiler and its appurtenances, and, therefore, is not chargeable to the character of the fuel. It is one of the most important factors in fuel efficiency.

Fourth, loss of heat by removing ashes at too high a temperature. This, by care, may be reduced, but not entirely avoided.

Fifth, loss by radiation. This may be reduced by increasing the thickness of walls and covering all exposed portions of the boiler. But from a practical standpoint it can never be entirely avoided.

The losses resulting from incomplete combustion are manifestly due to inadequate supply or imperfect distribution of the air. The presence of smoke indicates an absolute loss. Although this seldom exceeds one per cent. in ordinary practice, even this amount may be almost entirely eliminated and the smoke nuisance may, in most cases, be practically avoided by such regulation of the air supply and the intensity of draught as is possible under the conditions of mechanical draught.

Nearly forty years ago, Rankine wrote that "in furnaces where the draught is produced by means of a blast pipe, like those of locomotive engines, or by means of a fan, the quantity of air required for dilution, although it has not yet been exactly ascertained, is certainly much less than that which is required in furnaces with chimney draughts; and there is reason to believe that on an average it may be estimated at about one-half of the air required for combustion." Such has since proved to be the fact.

Theoretically, the amount of air chemically required for the combustion of one pound of coal is about 12 pounds; but practically, with chimney draught, the amount actually supplied, including that resulting from leakage, is far in excess and varies greatly under different conditions. Donkin and Kennedy have shown by gas analyses that, in the case of sixteen different plants, the air supply ranged between fifty-six per cent. and three hundred and twenty-eight per cent. in excess of the chemical requirements.

If the air is supplied in excess of that necessary for perfect combustion, there

is a definite loss, disregarding that due to moisture in the air, which is twofold in its character:—First, the excess of air entering the furnace is heated by the burning fuel, thereby lowering the temperature of the mixture of gases and air below that which would prevail if the gases only were present. As a consequence, the rate of absorption of heat by the water is reduced, for it is dependent upon the difference in temperature between the water and the gases.

Second, owing to larger volume and higher velocity, there is less time to part with the heat, and the temperature of the mixture of gases and air escaping to the chimney is higher than would be the case if there were no excess of air, while the increased volume is such that the total amount of heat thus carried away, without exerting any useful effect, is greatly increased. In other words, paradoxical as it may seem, the larger the volume of air supplied, the higher will be the temperature of the escaping gases.

A high furnace temperature and low stack temperature, other things equal, are evidently conducive to greater efficiency. It has just been shown that such conditions are incident to a reduction in the excess of air supplied. But perfect combustion with a small supply of air will result only when it is intimately distributed throughout the fuel. For such intimacy of contact intense draught and a clean and reasonably thick fire are necessary, conditions which may be most readily maintained by means of mechanical draught.

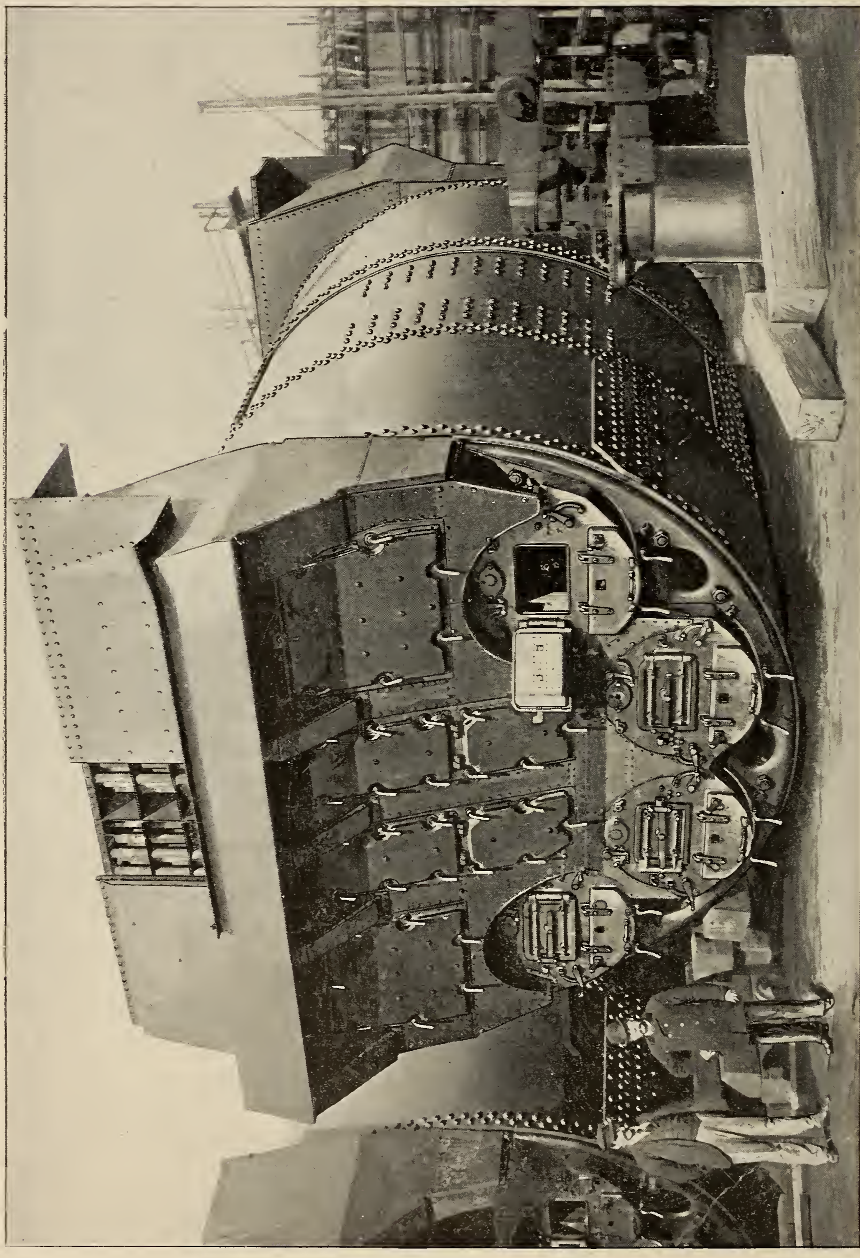
With a thick fire the air is compelled to come in contact with a greater amount of fuel and afforded a better opportunity to promote perfect combustion. This points to the efficiency of reasonably high rates of combustion. When secured under proper conditions, with a given grate area and boiler, any increase in the rate must be accompanied by an increase in the total air supply, and hence a probable increase in the temperature of the escaping gases. But if the total consumption remaining the same, the grate area be reduced, the rate of combustion per square foot of grate will of necessity be increased, and the efficiency of combustion may be greater. Clark states that "the proportion of surplus air required appears to diminish as the rate of combustion and the general temperature in the furnace is increased," and that "the system of forced draught opens the way for increase of efficiency in facilitating the adoption of grates of diminished area in combination with acceleration of combustion."

With a decreased supply of air, the intensity of the fire is increased, its temperature is higher, more heat is radiated to the exposed boiler surfaces, and more is taken up by the gases. Furthermore, the diminished superficial area of the grate and of the exposed interstices between the fuel necessitates a higher velocity to secure the admission of a given volume of air. This increased velocity in turn requires greater draught or air pressure.

If a given grate be reduced one-half, and the rate of combustion be doubled, the same volume of air would have to travel through the exposed interstices at twice the velocity. But the pressure or vacuum required to produce this velocity would be four times as great, and, as a consequence, the air would be forced or drawn into spaces between the fuel which it could not reach under less impelling force. Much more intimate contact and distribution are the results. Less free oxygen passes through the fuel bed unconsumed, and for a given supply of air a higher efficiency of the fuel is attained.

Undoubtedly the source of the greatest loss in boiler and fuel efficiency lies in the usual high temperature of the escaping gases. In seventeen independent boiler tests, Donkin & Kennedy found the heat lost up the stack, when no economiser was used, to range between 9.4 per cent. and 31.8 per cent. of the total heat of combustion.

With the chimney, a comparatively high temperature of the rejected gases is an absolute necessity for the production of the draught. Its production by means of a fan is, on the other hand, independent of the temperature of the



BOILER EQUIPPED WITH HOWDEN HOT-DRAUGHT FOR USE WITH STURTEVANT FANS ON THE STEAMSHIP "ST. PAUL," OF THE AMERICAN LINE.

gases, and there is, therefore, opportunity to utilise the heat which is a positive and unavoidable loss in the case of a chimney.

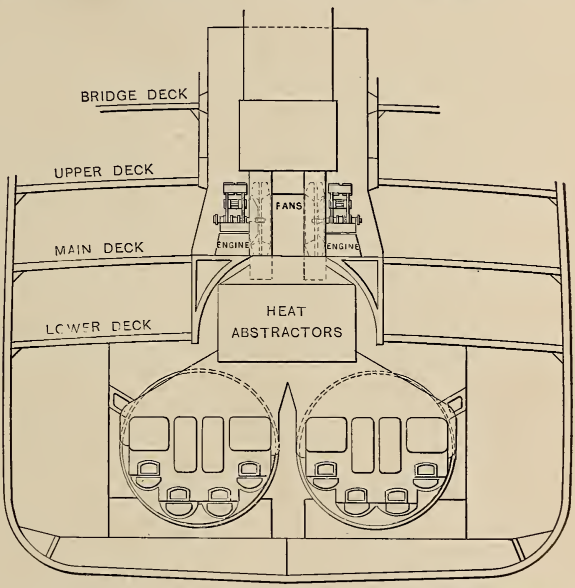
In this direction lies one of the greatest opportunities for increasing boiler efficiency. Although additional surface may be obtained by reducing the size of the tubes and increasing their number, or by ribbing them, or introducing retarders, it is usually customary to abstract the surplus heat from the gases by some means in a sense independent of the boiler. It may then take the form of a feed-water heater, otherwise known as an economiser, or the form of a device for abstracting the heat from the gases and transferring it to the air supplied to the fuel, or both.

The results obtained by any of these methods have, in the case of chimney draught, always been restricted by the cost of the excessively high chimney necessary to produce the requisite draught with the decreased temperature and increased resistance. The simplicity and efficiency of mechanical draught, however, obviates this difficulty, and makes possible the attainment of a much lower final temperature of the flue gases with a corresponding increase of efficiency. So far as production of draught is concerned, the gases may be cooled down to atmospheric temperature, but the practical limit is necessarily above this because of the expense of the abstracting apparatus required.

Numerous forms of heat abstractors have been devised for the purpose of transferring the heat from the escaping gases to the entering air. The Howden apparatus, which is largely employed on shipboard, is illustrated on page 54. Forced draught is used. Another system, known as the Ellis & Eaves, is provided with larger abstracors and is operated by induced draught.

Retarders in the tubes, as well as such devices as the Serve ribbed tubes, have shown a considerable economic gain, by a reduction of the stack temperature, and with both mechanical draught has been shown to be most desirable.

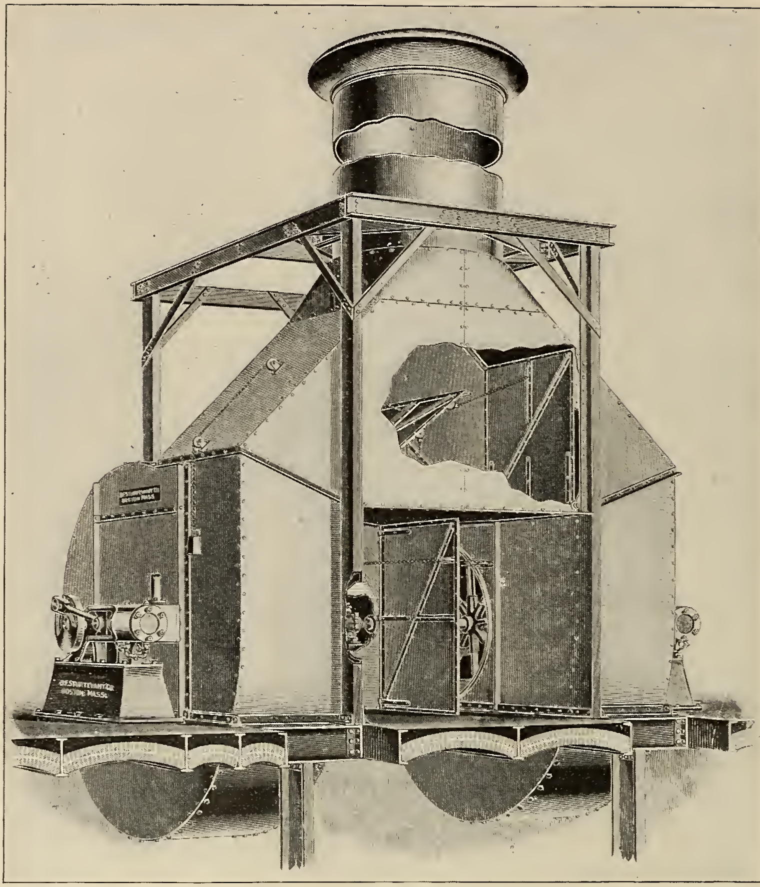
We may now consider the influence, from a commercial standpoint, which the application of mechanical draught exerts upon the aggregate first cost of a steam-boiler plant. For this purpose there has been selected a plant of reasonable size of which the detailed cost is known. This plant consists of 8



THE BOILERS, FANS AND HEAT ABSTRACTORS IN THE STEAMSHIP "KENSINGTON."

modern water-tube boilers, each of 200 horse-power normal rating, set in pairs, making a total of 1600 horse-power. A chimney is provided, 8 feet in internal diameter and 180 feet high, of sufficient capacity to overcome the resistance of the two feed-water economisers and produce the draught necessary for any probable forcing of the boilers. The detailed cost of that portion of the plant which concerns the present discussion is, in round numbers, as follows :—

8 water-tube boilers of 200 horse-power each	$25,000.00
2 feed-water economisers	7,000.00
Boiler and economisers, setting and by-pass	6,000.00



A DUPLEX FAN FOR A BOILER PLANT, MADE BY THE B. F. STURTEVANT CO., BOSTON AND LONDON.

Automatic damper regulator and dampers	300.00
Chimney, complete	9,000.00
Building, complete	11,000.00
	$58,300.00

In the other plan there are two fans, each driven by a separate engine. Each fan is capable of independently producing the draught for the entire plant, and thus serves as a relay, if desired. Such an apparatus, with the short stack, can be installed complete, under ordinary conditions, for about $3500 (£700). The total economy in first cost effected by the introduction of the mechanical draught plant, which amounts to a reduction of about 62 per cent., may be indicated as follows; the saving of space occupied by the chimney being neglected:—

Chimney Draft.

Cost of chimney	$9,000.00
Cost of damper regulator and dampers	300.00
	$9,300.00

Mechanical Draft.

Cost of fans, engines, draft regulator, and short stack, installed complete	$3,500.00
Saving by use of mechanical draft	5,800.00
	$9,300.00

A still further reduction might have been secured by designing the plant so as to operate the boilers at somewhat above their rated capacity, as could be readily done by means of the same mechanical draught apparatus. The omission of one boiler would bring the rated capacity down to 1400 horse-power, and would call upon the fans to increase the steaming capacity of the other boilers by only about 14 per cent. above the

normal. This would show an additional saving in first cost which may be thus presented:—

1,600 Nominal Horse-Power Plant.

Cost of 8 boilers	$25.000.00
Cost of settings, etc	6,000.00
Cost of building	11,000.00
	$42,000.00

1,400 Nominal Horse-Power Plant.

Cost of 7 boilers	$21,875.00
Cost of settings. etc., about	5,500 00
Cost of building, about	10,500.00
Saving by use of mechanical draft	4,125.00
	$42,000.00

This shows a possible supplementary saving on the entire plant of $4125 (£825), which makes a total reduction of $9925 (£1985) to be credited to the account of the mechanical method. Of course, the fixed charges for interest, taxes and insurance will be correspondingly reduced. Had this comparison been based upon the cost of a plenum or forced draught plant, the saving in the cost would have been shown to be even greater because of the smaller fan required.

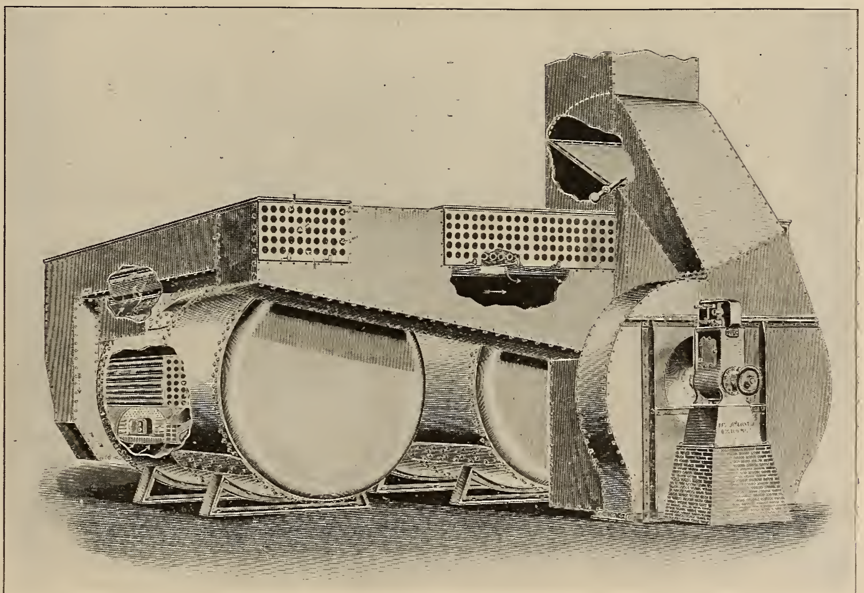
In any properly arranged plant the exhaust steam from the fan engine would be utilised so that the actual cost of the steam used in producing draught would be reduced to practically nothing.

The value of the land may be an important factor in first cost. If figured at $2 (8 sh.) per square foot, for instance, the omission of the chimney would in this case save $990 (£198), and the reduction in the number of boilers, $960 (£192) on the cost of the land required for the plant.

The total net saving in first cost of a single plant, under the given conditions, may be thus summarised:—

By omission of chimney and damper	$5,800 00
By reduction in number of boilers	4,125.00
By saving in space occupied by chimney	990.00
By saving in space by boiler omitted	960.00
	$11,875.00

This total saving is made possible by the expenditure of $3500 (£700) for the mechanical draught apparatus; that is, the saving is nearly three and one-half times the expenditure necessary to secure it. The reduction of $11,875 (£2375) in the cost would indicate an annual saving in fixed charges of about $831 (£166) to $890 (£178), accord-



INDUCED-DRAUGHT PLANT ON THE ELLIS & EAVES SYSTEM AT THE STEAMSHIP PIER OF THE AMERICAN LINE, NEW YORK.

ing as the aggregate of interest, taxes and insurance is taken at 7 or 7½ per cent.

This amount would, under conditions of the best economy, be practically sufficient to cover the cost of operating the mechanical draught apparatus, provided no attempt was made to utilise the exhaust steam, and would far more than cover it were this steam usefully employed. When to the economical advantages already pointed out is added the increased convenience of mechanical draught, its positive character, its ready adaptability, its independence of climatic conditions, and its instant response to any demand for increased steam supply, the account stands decidedly to its credit. Therefore, any further saving, as, for instance, in the cost of the fuel burned, is clear gain over and above any expenditure that may have been made on account of the introduction of this method.

Under ordinary conditions the steaming capacity of boilers may be greatly increased by the application of mechanical draught. This is equivalent to a reduction in the number of boilers required to secure the same capacity. Howden has shown that in the case of a certain vessel the cost of the boilers, fittings and connections, for the same output was $63,000 (£12,600) less with his system of forced draught than with natural draught. Such a reduction on shipboard is twofold in its effect, for it leaves so much more space unoccupied and thereby increases the carrying capacity of the vessel.

As a further factor in the matter of cost it should be noted that the fan possesses a definite advantage over the chimney in that it is portable and is always a valuable asset. The chimney, on the other hand, is a fixture; it is suited only to certain conditions and is practically valueless unless those conditions exist.

The largest and most important factor in the operating expense is the cost of the fuel itself, which should be measured, not by the number of pounds, but by the available heat units obtained for a given price. In this cost are properly included the transportation charges, the expense of getting the coal into the boiler house and putting it into the furnace as well as taking out and carrying away the ashes.

The ability to utilise cheap fuels is an inherent advantage of mechanical draught, due to the fact that such fuels, being, as a rule, finally divided, with a large percentage of dirt and ash, require an intense draught for their combustion.

In addition to the economic advantages of mechanical draught which have been presented, there are others which relate primarily to the convenience of installation and operation. Prominent among these is the feature of adaptability. The fan, which is usually of steel plate, may be constructed in any shape to meet specific requirements, may be located as desired with regard to the position of the boilers, and, without expensive foundations, may be used for either forced or induced draught, and, because of its portability, may be relocated or exchanged for another of different capacity. In its operation it is perfectly flexible, may be run at high or low speed, independently of the chimney temperature, and is always susceptible of instantaneous change in response to sudden demands. A mere change in engine cut-off produces an effect secured with a chimney only by adding to its height at great expense.

External temperature changes have no appreciable effect upon the operation of mechanical draught, which above all else is independent of climatic conditions. The fan is a most important factor in smoke prevention, and in connection with the closed-fire room system the resulting ventilation is of vital importance.

Briefly summarised, mechanical draught has here been shown to be capable of reducing the avoidable losses, of decreasing the first cost of a steam generating plant, and of reducing the fuel expense. In addition, it presents certain marked conveniences in the matter of installation and operation. In these days when every step in the process of steam generating and utilisation is being scrutinised in the attempt to reduce the

cost by even a single per cent., the opportunity presented by the employment of mechanical draught cannot be and is not overlooked. The economical necessity was not so imperative when Rankine and Clark, long ago, pointed to its marked advantages; and the future was but dimly discerned when, only fifteen years ago, Seaton referred to the chimney as a rough and ready, but exceedingly wasteful, way of inducing the air to flow into furnaces with sufficient velocity to cause the fuel to burn, and prophesied that it would some day be superseded by more scientific and economical apparatus.

What these men foresaw, we to-day realise. Mechanical draft now stands so well established in the engineering world as to lead a noted engineer to remark that "the building of tall chimneys to secure draught simply advertises the owner's lack of familiarity with modern improvements, or his want of confidence in results easily demonstrated."

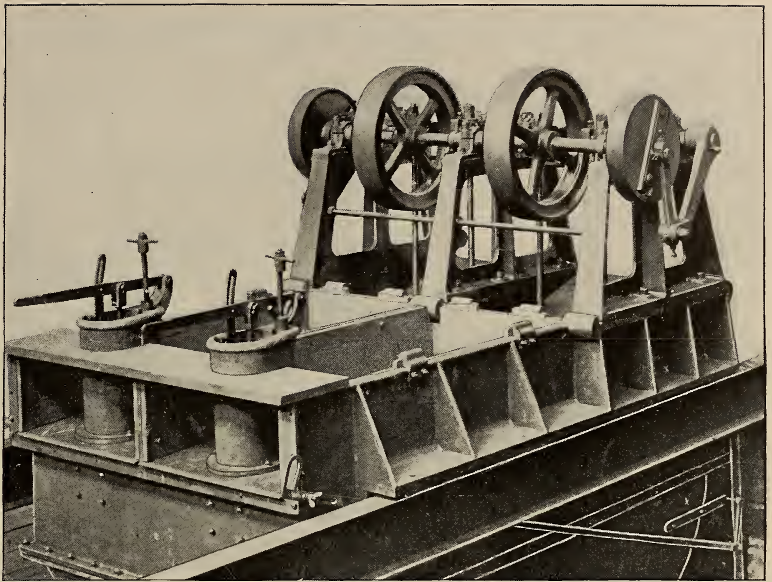
COAL WASHING.

By H. L. Siordet, Associate of the Royal College of Science.

THE object of a coal washing plant is to rid the coal which comes from the pit of all stones, slate, shale, pyrites and other impurities, with which it is always mixed to a greater or less extent. Some coals have these impurities finely disseminated all through them, and in that case it is necessary to disintegrate the whole bulk in order to be able to properly separate the coal. Other coals contain the impurities in greater or smaller lumps, many large lumps of coal being practically quite free from foreign matter. In that case it is generally the custom to preserve the large lumps for the market as nearly whole as possible, and with soft coal especially great care is taken in handling it so as not to break it up more than can be helped.

When the impurities occur in lumps sufficiently large to be readily detected by the eye, the process of picking these out by hand is resorted to with advantage. The usual method employed in washing coal embodies a practical application of the different specific gravities of the component parts of a mass

A COAL WASHING PLANT ERECTED BY THE HUMBOLDT ENGINEERING WORKS CO., KALK, NEAR COLOGNE ON THE RHINE, GERMANY.



COAL WASHER MADE BY THE HUMBOLDT ENGINEERING WORKS CO.

of coal as it comes from the mine. Of the two bodies of the same size the one with the greater specific gravity will sink the faster when placed in water. Now if the water in which the bodies are immersed be agitated in such a way that a continuous upward pulsation is produced it may be possible to regulate this pulsation in such a manner that the lighter body is kept floating and can be washed over, whereas the heavier body remains at the bottom. This is the principle of the jig or washer.

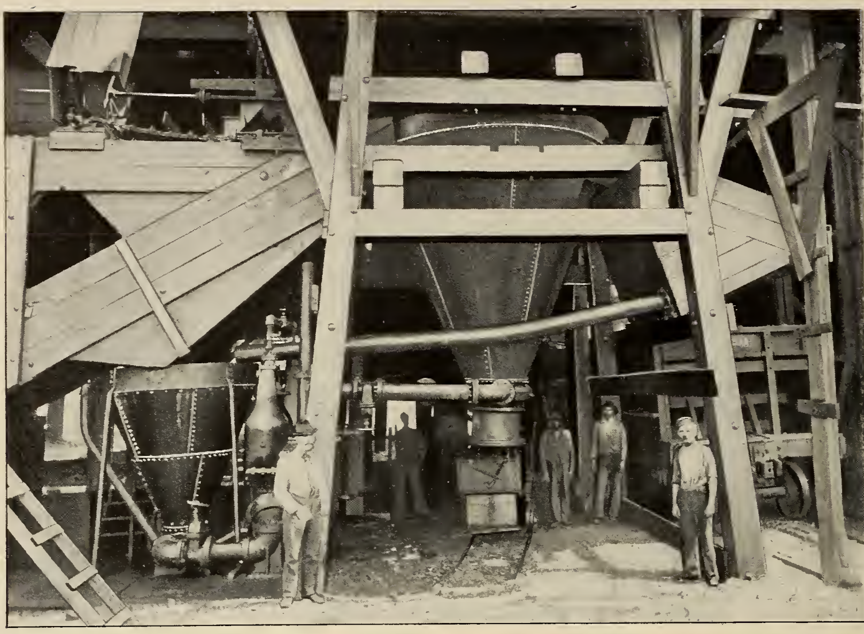
The mixed coal or shale is brought into a box or tank filled with water, running over, and the water is kept moving up and down by successive strokes of a plunger or piston.

It will be evident from the above that besides the washer proper a thorough arrangement for classifying is necessary in a coal washing plant, otherwise there would be large pieces of low specific gravity and small pieces of high specific gravity collected together at the bottom of the washer. With ore dressing it is, in most cases, the valuable products which have the greater specific gravity, whereas with coal it is almost invariably the impurities that are heavier.

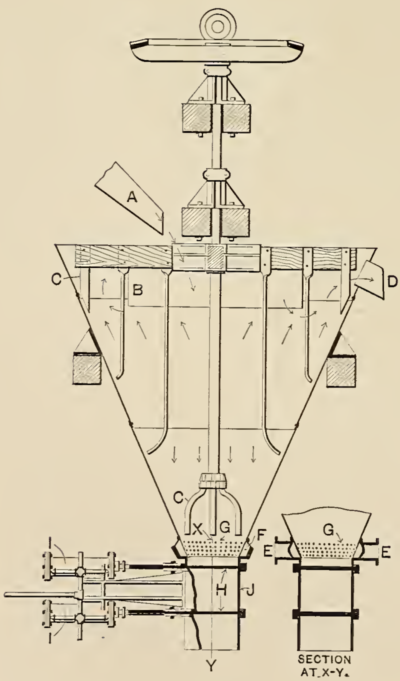
Let us assume that the coal to be dealt with is sufficiently pure in the larger lumps to go straight to the market, and that the shale or impurities occur as lumps of all sizes! The coal is brought up from the mine in tubs or small waggons. These are run into so-called tipplers which turn the whole waggon over, emptying the contents on to a screen. According to the value laid on the coal not being broken up through rough treatment, various devices are applied, both to the tipplers and the screens.

The former may be provided with special shoots or aprons to allow the coal to slide gently on to the screen, or the tippler itself may be driven with a variable speed, having a relatively slow motion whilst the coal is being emptied.

The screens may be of various kinds. The simplest of these is the common bar-screen, consisting of bars laid usually on an incline and placed at certain distances apart. The small stuff falls through the spaces and is treated in further machinery, and the large stuff slides along the bars, to be afterwards either hand-picked or loaded at once into railway waggons for transport.



A COAL WASHING PLANT EQUIPPED BY THE JEFFREY MFG. CO., COLUMBUS, OHIO.

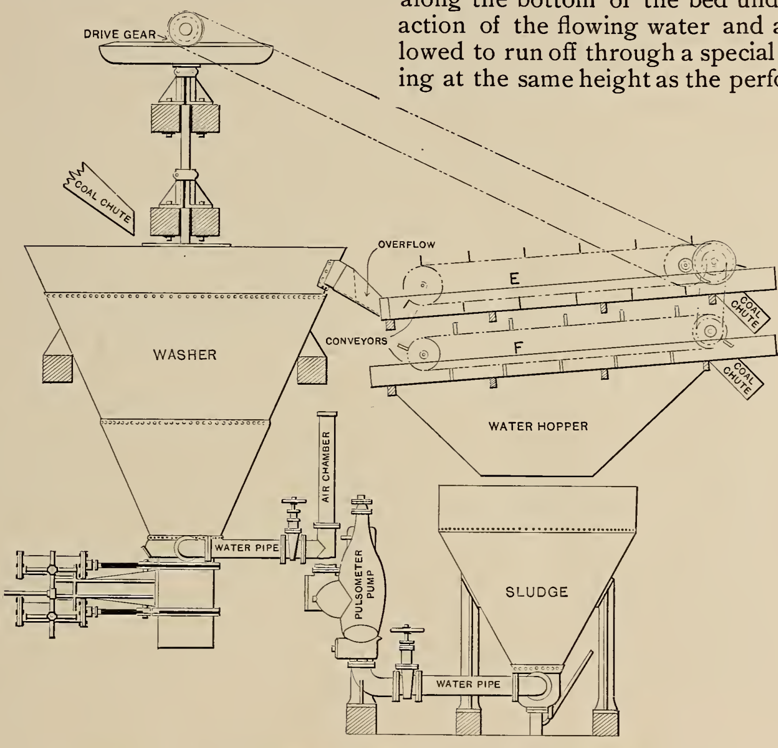


SECTION OF A JEFFREY-ROBINSON COAL WASHER.

Many other screens are devised for screening off the small stuff and moving the large along gently. One of these ingenious contrivances is the Humboldt-Klein screen, which throws the coal upwards and forwards and catches it again gently further along the screen.

If the large stuff is still composed of lumps of coal and of stones, it is usual to submit the whole to the process of hand picking. This is done by passing the rejection from the bar or other screens on to an endless band, or metallic belt, called a picking band. Boys or girls stand along each side of this belt and as the coal slowly moves past them, they pick out the stones and rubbish, and the coal itself runs off to the railway waggons. Care has again to be taken not to let the large coal drop from any great height into the waggons, and for this purpose devices, such as anti-breakage shoots, are used. These are endless bands which can be lowered down to the bottom of the trucks, or raised, and carry upright angle irons or plates at certain distances apart, which, in moving down the incline, carry the coal gently along with them.

The stuff which is small enough to fall through the bar or other screens, called the screenings, must now be separated into pieces of equal size. This is usually done in a revolving screen with several concentric shells, each having different-sized perforations. The different sizes fall down troughs or launders direct into the coal washers, of which there are one or several for each size, according to the quantity of stuff to be treated. The revolving screen has, of course, the number of shells proportioned to the number of sizes of washed coal required for the market.

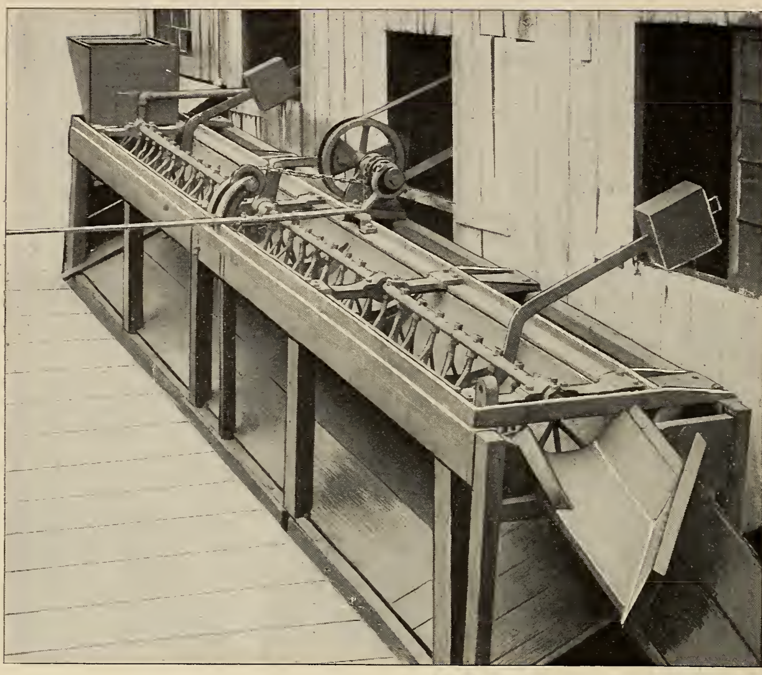


ELEVATION OF A COAL WASHING PLANT BUILT BY THE JEFFREY MFG. CO.

As a rule, two distinct kinds of washers are used in a coal washery. The one kind is called a coarse washer, and is used for treating any size down to, say, ½″ or ⅜″; and the other is called a fine-washer, as it treats any size from, say, ½″ or ⅜″ down to dust.

The washers are both arranged with a bed of perforated metal on which the stuff to be treated is deposited. In the coarse washer these perforations are smaller than the stuff to be treated. The coal, which is lighter, is carried away, over the top of the washer, having been raised sufficiently by the palpitating action of the piston on the water; the impurities, on the other hand, being heavier, are not raised by the jigging action of the piston, but run along the bottom of the bed under the action of the flowing water and are allowed to run off through a special opening at the same height as the perforated bed. This process is called washing over the bed.

In the fine washers the process is somewhat different. Here the perforations of the metal bed are larger than the stuff to be treated; but instead of the stuff coming on to the metal bed direct, this is covered by a layer of coarse felspar, which cannot pass through the perforations. The light stuff, or coal, is again washed over the top of the washer, but the heavier impurities find their way gradually through



A TROUGH WASHER, SHOWING THE TROUGH RAISED. BUILT BY THE SCAIFE FOUNDRY AND MACHINE CO., LTD., PITTSBURGH.

the felspar bed and through the perforated sheet and are deposited in the bottom of the body of the washer, whence they can be run off to the rubbish heap. This latter process is called jigging, or washing through the bed.

Of course, the water used in these washing machines carries off a quantity of fine particles of coal in suspension, and in order to collect this, the overflow water from the washers is run off to settling pits, where the sludge is deposited. The water, when sufficiently clarified, is pumped back to the washers. The fine sludge is then let off from underneath the settling tanks or pits and is often carried to its destination by a scraper conveyor.

The illustration on page 61, represents a coal washer of the general type just described, built by the Humboldt Engineering Works Company, of Kalk, Germany, and clearly shows some of the working details mentioned.

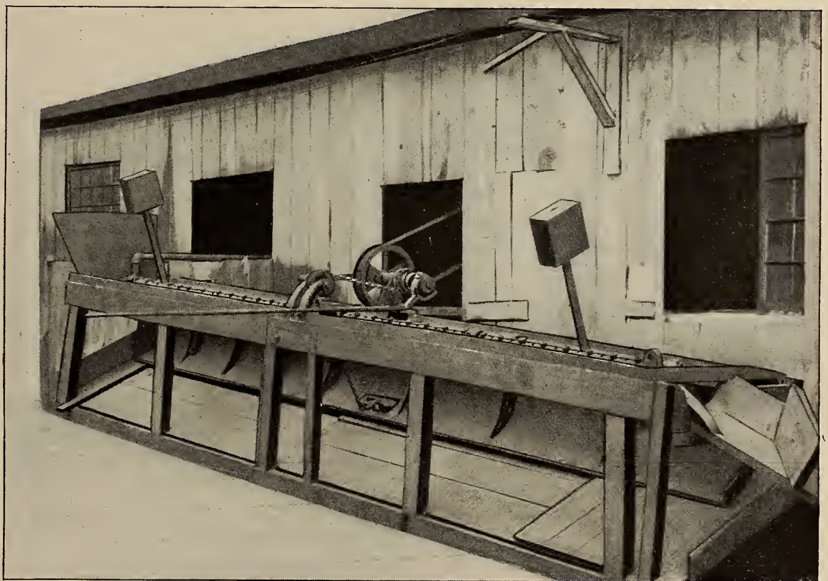
On page 62 is shown a sectional view of an American machine built by the Jeffrey Manufacturing Company, of Columbus, O. It consists principally of a well-built cone, of heavy plate steel, having at its lower end a specially arranged water jacket. Inside this cone is a rotating shaft provided with arms and blades, and operated by power from the head, as shown. This shaft is turned at the rate of about eight revolutions per minute. The blades projecting down into the cone keep the material in a constant state of agitation. The lower end of the cone is provided with two valves, operated by means of levers. A water tank or reservoir is usually arranged overhead, although in some cases the water is fed direct from the pump through pipes connected with the water jacket, out of which the water passes into the washer through various openings so as to supply it equally on all sides. The force of the water is regulated by means of valves so that the pressure is made to correspond with the specific gravity of the coal that is being washed. The overflow water is collected in a suitable tank and by means of a pulsometer pump is again forced

into the reservoir or direct to the washer.

The coal passes into the centre ring *B* of the washer from spout *A*, while the water supply enters at *E* through perforations *G*. The coal is kept in a continual state of agitation, and, as it sinks into the tub, is met by the upward current of the water; the good coal being lighter in weight than the impurities, is forced upwards, as indicated by the upward turned arrows, and out at *D*; the impurities, being heavier in weight, sink below in the direction of arrows turned downward, and are collected in the chamber *J*. When this is filled, the upper valve *H* is closed and the lower valve *H* is withdrawn; this allows the accumulated refuse to be discharged, after which the lower valve *H* is closed and the operation is repeated.

A general elevation of an outfit using this washer is given on page 63. The good coal passes from the washer proper on to inclined perforated chutes or screens, and is freed from the water, after which it is either carried by means of conveying machinery to storage bins or falls direct into the cars. The water from the overflow is collected, and by means of the pump is again forced into the tank or washer for further use.

Another type of American machine is the trough washer, one of which is shown in the illustrations on this page and the one opposite, being made by the Scaife Foundry and Machine Company, Ltd., of Pittsburgh. In this case the body of the washer is a rigid, almost semi-circular iron trough, two feet in diameter and twenty-four feet long. Its movable side is strengthened somewhat to facilitate the discharge of impurities. Inside it has a series of fixed dams or partitions, which can be readily made higher or lower by bolting plates to them or by cutting, should the nature of the coal require such changes.



THE SCAIFE COAL WASHER. TROUGH LOWERED.

The trough is made so heavy that it should last many years without repairs. It is carried along one side by a series of hinges which attach it to a cast iron frame supporting the whole apparatus. A shaft running the entire length of the trough turns in babbitted journals bolted to the frame. It is given a reciprocat-

ing motion by means of an arm in its centre, worked by a connecting rod attached to the flanged driving pulley. As the trough and frame are inclined, the driving pulley on the main shaft should be moved along its shaft a little out of line, in order to make the belt run properly. This pulley should also have a clutch to start and stop the washer.

On one side of the washer pulley is seen an iron spool with its chain, clutch and operating lever. The latter has a steel tongue which enters an eye in the centre of the movable side of the trough and thus holds the trough up. The long shaft carries a considerable number of stirring arms or forks. Two large weights, supported by forged arms fastened to the trough, counterbalance the greater part of the weight of the empty trough, and throw it back as far as desired when dumping the refuse. These weights are movable along the arms, so that their lifting moment can be varied at will. The lifting chain is wound a couple of times about the spool, and at its lower end is a weight (not seen in the illustrations) which gives the necessary tension to the chain, and partly counterbalances the weight of the filled trough.

Coal is fed with water at the upper end of the trough. By the combined action of the flowing water and stirrers, the slate, pyrites and other impurities settle to the bottom and are caught behind the dams in the trough, while the clean coal passes over the top and out at the lower end. When the spaces between the dams are entirely filled with impurities, the supply of coal is stopped or it is temporarily turned into an adjacent washer, and all the remaining coal is washed over the dams. The operating lever is moved a few inches to the right, which draws the steel tongue out of the eye and allows the trough to drop free and discharge the refuse.

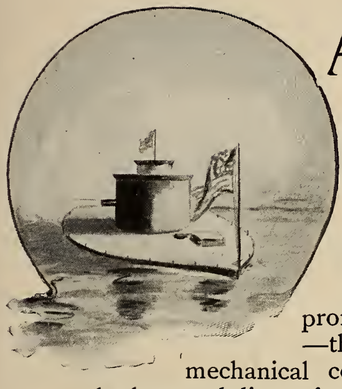
Should any dirt remain in the trough it can be quickly washed out by means of a water box or pipe discharging into the entire length of the lowered trough. By moving the lever a few inches still further to the right, the spool clutch is thrown out and the trough raised. The washing is then recommenced.

Probably nowhere has coal washing been so highly perfected as in Germany, due to the pressing needs there of a process of this kind because of the relatively large amount of impurities carried in German coals. The Essen district is particularly remarkable for its many coal-washing plants, clustered round about the town of that name, and they all give evidence that the Germans have spared neither money nor thought to make these plants, with all their intricate machinery, models of completeness.

One of the striking features in some of the best coal washing plants of the district is the cleanliness within the buildings, considering the nature of the material treated. It is a fact that one may spend a whole day in some of them without so much as soiling one's white collar, and at the end of the day one is certainly not more in need of a wash than after a couple of hours' walk through the average manufacturing town burning soft coal. Where such coal washing plants are erected on a large scale, one finds, as a rule, that everything connected with the mine is in keeping; for instance, the winding plant, the pit-head gear and other details; and the comfort of the workmen and colliers is also well attended to. Warm baths are on the spot for all the men, and it is a pleasant sight to see a shift of men coming up from the mine all spick and span, with no trace of the pit left on them.

COMPRESSED AIR ON WARSHIPS.

By Passed Assistant Engineer T. W. Kinkaid, U. S. N.



A VISITOR on board a modern man-of-war, be it cruiser or battle-ship, must, after only a cursory examination of the vessel, be impressed chiefly with two prominent features,—the multiplicity of mechanical contrivances, and the heat and discomfort encountered on the lower decks of the ship. The mechanical devices are labour savers; and their builders attempt to combine in their designs the characteristics of great power for space occupied, lightness, economy of energy consumed, durability, and freedom from noisome qualities.

Formerly all auxiliary machinery on board ship was designed to work by steam or by hand power. The disadvantages of steam as used to distribute power throughout a structure like a steamship, with its many closed compartments and tortuous passages, have long been evident; but new competitors, like hydraulic, electric, and pneumatic systems of power distribution, have had no quick triumph over steam. Engineers and mechanics are familiar with the ills of steam machinery, and, when difficulties arise, they are met with the accumulated skill and confidence of many decades. With new systems a new fund of experience must be acquired before the conservative will permit the ousting of the steam engine, in spite of its known tendency to unduly heat a compartment, to saturate the air with unwelcome moisture, to scorch adjacent woodwork, to produce unsightly rust stains, to first corrode then burst its piping, to produce obnoxious smells from its lubricating oil, and others more. Of course, much of the heat in the interior of a warship is due to the fact that the engines and boilers occupy perhaps two-thirds of the ship's length; but the numerous steam and exhaust pipes leading to and from the more or less distant auxiliary engines add greatly to the heat discomfort.

In considering the question of installing a compressed air system on board of a man-of-war, it must be recognised that there are two principal classes into which air motors can be divided, namely, those which are to run continuously or nearly so, and those which are used for short periods only. The character of the motor service reacts upon the design of the compressors. The continuously-run motors, as, for example, ventilating fans and flushing pumps, should appropriately be driven by air from an economical form of compressor. Such a compressor, in order to furnish a large output of air per pound of steam consumed, must possess the complication, high cost, and greater weight which are the inevitable concomitants of a high degree of economy. On the other hand, the motors which are only occasionally brought into use may not only be of the simplest construction themselves, but the air compressor associated with them should possess lightness, reliability, and cheapness rather than great economical efficiency that would be, in the end, dearly bought.

One of the mooted questions of compressed air service relates to the employment of reservoirs. In shore work,

where weight is not a bugbear to the designer, reservoirs are freely used as separators of moisture, and, when located near the motors, to steady the flow within the supply pipes. On board ship a reservoir of moderate size near the compressor is admissible, especially if the compressor be not kept constantly running; and it may sometimes be thought advisable, in the case of an intermittently-used motor, to locate a storage tank at the motor end in order to reduce the size of supply pipe from the compressor. Whether or not weight is saved by this arrangement, it is unquestionably easier and cheaper to lead a small pipe through bulkheads and around obstructions than it would to run a pipe one or two sizes larger.

Then there are special conditions which seem to warrant the storage of air at very high pressures in order that a supply at lower pressure may be available at short notice. This is the case on many battle-ships, where a small high-speed compressor fills a battery of steel flasks to a pressure of 2000 pounds per square inch, the pressure falling to about 1350 pounds when a torpedo is connected up and charged. The supply of air taken by one Whitehead torpedo weighs 50 pounds. On torpedo-boats, however, the flasks are not used, on account of the weight involved. The United States dynamite cruiser *Vesuvius*, which fires aerial torpedoes, carrying each an explosive charge of 500 pounds, stores air at a pressure of 1500 pounds per square inch.

A reservoir of sufficient capacity to operate a large motor for any considerable length of time must necessarily be of great weight and bulk, and would, therefore, be inadmissible on board cruising ships. Were it not for the drawbacks mentioned, it would be practicable for a man-of-war to utilise her surplus steam power, when lying at anchor, or when proceeding slowly, to pump up a supply of compressed air sufficient to operate her turret and magazine machinery and much of her auxiliary machinery during an entire action.

The location of a ship's air compressors should be in or near the engine rooms or fire rooms. This plan of location not only reduces the length of the steam and exhaust piping required, but also places the machines within reach of a body of mechanics who can attend to their regular steaming duties and to the compressors besides.

The air of the engine rooms is not suitable for use in a power transmission, not only on account of its comparatively high temperature, but also because of its high relative humidity. Modern practice aims to secure the air as cold and as dry as possible. The colder the supply, the greater the weight of air that can be taken by a given compressor in a given time.

Special air ducts should be led to the compressor valve chambers from the upper deck of the ship. Moisture manifests its injurious quality at the motor, where the expansion of the air under ordinary circumstances produces temperatures low enough to form snow if watery vapour be present. The snow thus formed is almost certain to clog the passages of the motor and put it temporarily out of use. It is sometimes the practice to inject water or even steam into the air supplied to the motor, but both of these plans are objectionable in the warm living spaces of a man-of-war. Heating the air at the motor not only obviates snow formation, but very greatly improves the economic efficiency — sometimes as much as 50 per cent. But reheating devices, if used on board ship, would destroy at once one of the great advantages of a compressed air transmission.

When power is to be transmitted to a considerable distance, the high temperature resulting from the compression of the air is sure to be lost before the motor is reached, and therefore it is advantageous to cool the air in the compressing cylinder, compressing it as nearly isothermally as possible, and thus economising power. But on shipboard the length of the transmission is not great and a moderate amount of cooling suffices, especially if the transmission pipes are to be lagged. It is

necessary for the smooth running of air pistons, and for their tightness as well, to provide a steady lubrication, and the oil used undoubtedly interferes with the cooling efficiency of the jackets. On the other hand, the oil supplied to the compressor cylinder is carried along with the air and ensures the lubrication of the motor cylinders and the preservation of the interior surfaces of the piping.

Piping on shipboard is necessarily very tortuous, and much of the resistance to the air in its transmission is due to bends and elbows. A pressure of 80 or 90 pounds per square inch should be used. High pressure is suitable for the intermittently used motors, as it keeps their size down to convenient limits; but excessive pressure not only means a loss of economy in the operation of the continuously-run motors, but increased liability to leakage also. If a motor be run sometimes fast and at other times slowly, there will, in the latter case, be considerable throttling of the air, because at the reduced speed the full pressure of the main cannot be utilised. The expansion of the air under such circumstances may produce such a low temperature as to seriously interfere with the working of the motor. The remedy, one which has been suggested by mining practice, is to provide a throttle valve at some distance from the motor, so that the air, cooled by expansion (wire-drawing), can again absorb heat from surrounding objects. The motor cylinders should not be lagged; in fact, their exposed surface should be large, so as to favour the absorption of heat from the warm atmosphere of the compartment.

Recently manufacturers of jet blowers have effected improvements in their apparatus which seem to place these blowers on an equal footing, as regards economy, with the ordinary simple reciprocating engine using steam or compressed air to drive a fan. Although there is not much danger from snow formation in the motors used on the lower decks of a man-of-war, yet the jet blower obviates that difficulty entirely and at the same time effects a great economy in the weight of the ship's ventilating apparatus and in that of the forced draught appliances of the boilers. Induced draught is considered the most desirable form of artificial draught. It is certainly the most convenient and the one least harmful to furnaces and tubes; and the jet offers the simplest means of obtaining it. Rotary engines are much used in air power transmissions aboard ship. They are not economical, but they are compact and light, and well adapted for winch service, for example.

The double-bottom compartments of a warship must be fitted with means for freeing them of water, although it is likely that for a majority of the compartments such means will never be brought into requisition. The long lines of expensive and heavy piping which are commonly run from the various compartments of the double bottom to the auxiliary pumps could be dispensed with entirely were means provided for putting a moderate pressure of air in any compartment, the water being expelled in such a case through a short pipe into the bilges above. In the case of a badly leaking compartment, an air pressure of ten to fourteen pounds per square inch would probably suffice to control the leak; and this would seem to be a more satisfactory expedient than to attempt to " pump out the whole ocean."

It is pretty well settled that at least 40 or 50 per cent. of the steam indicated horse-power of the compressing engine can be indicated at the motor. In considering the steam and compressed air systems competitively, we have the facts that in the steam pipe to the small steam motor there is loss by condensation and loss by friction of the moist steam, and in addition, the well-known wastefulness of small engines as compared to the large triple expansion engine of the central compressor. The central compressing engine has short steam pipes and exhaust pipes, while the small distant steam engine has long piping with many elbows and unions. As regards consumption of steam, therefore, the two systems are about on a par.

In the matter of weight, it is probable

that the steam system still has the advantage, in spite of the fact that the air motor needs no return exhaust pipe, its exhaust being direct into the surrounding atmosphere,—a grateful, cooling addition to the local ventilation. The weight of the compressor can be kept down by adopting high speed, but at the risk of reduced economy due to wire drawing in the steam ports and also in the air ports.

The shrill noise made by the exhaust of air from a motor is obviated by employing some simple form of muffler. Leading the exhaust into a cylinder full of pebbles has proved an effective and cheap plan; but, of course, the muffler adds to the back pressure and also to the total weight of the system.

In a paper read by Fleet Engineer John T. Corner, R. N., before the Institution of Mechanical Engineers, at Portsmouth, several years ago, that writer gave the following description of a successful compressed air installation for dockyard service:—

"In the most modern part of the dockyard the lifting and hauling appliances are worked chiefly by compressed air; the only exceptions are the heavy cranes and sheers, which are worked by steam power direct. The air is compressed to 60 pounds pressure per square inch, into eight wrought iron receivers having a total capacity of 18,000 cubic feet. The compressing is done by one or the other of two separate sets of pumps. One set consists of two pairs of compressing pumps worked through gearing, either separately or together, by a pair of simple engines of 90 I. H. P. The other set of pumps is worked by a pair of compound beam engines of 200 I. H. P. This machinery is situated at the main pumping station, about the centre of the yard; and, besides the air compressing machinery, the same building contains the main dry dock pumping machinery of 1000 I. H. P., and two pairs of 120 H. P. engines for general fire and dock drainage purposes. The larger set of air compressing pumps will fill the eight receivers to 60 pounds pressure in one hour. No case of a receiver bursting has occurred here; and there is no record of a pipe having been replaced during the last two years. There is also less trouble with air joints than with steam and hydraulic joints.

"The air pipes, which have a total length of 14,000 feet, or about 2⅔ miles, vary from 3 to 12 inches in diameter, extend around the large basins, and are connected to forty 7-ton capstans, to five 20-ton cranes, and to the machinery for working seven caissons besides driving a small workshop engine. The air pressure is also used occasionally for driving small engines for carrying out machine work on board ships building, and it has further been connected with the auxiliary steam pipes of some of the larger battle-ships, so that air pressure could be used instead of steam for driving the hydraulic pumping engines on board ships for working the gun gear for drill purposes, and also for driving the electric light engines and other auxiliary machinery on board. This obviates the necessity of getting up steam in the ship's boilers, thus admitting of their being kept systematically in a certain condition, either closed and dry, or quite full of water, which would be impractical if they were being used at irregular intervals and at short notice."

In air lifts using pistons, a single stroke of which affects the entire lift, jerkiness is apt to be experienced unless a variable hydraulic resistance be opposed directly to the piston. Oil or glycerine is the liquid used, the resistance to the flow of which varies as the square of the speed.

An interesting application of compressed air in the United States Navy is found on board the monitor *Terror*. In this vessel air is used for taking up the recoil of the guns and running them out to battery after firing; for rotating the turrets; for elevating and depressing the guns; for all the movements of the breech plug, except locking it; for working the telescopic rammer; for blowing out the powder gases, when the breech is opened; for picking up and hoisting the ammunition; and for steering the ship. Even in vessels fitted with hydraulic systems, compressed air

is usually employed in the accumulators. The accumulator of the U. S. S. *Monterey* is of this type.

On the *Terror* there are two main compressors, one situated near the forward turret, the other near the after turret. By means of a communicating pipe, nominally 8 inches in diameter, either compressor can supply either turret. A smaller high-speed compressor, located in the main engine room, supplies the air for steering, and also answers for light service in the turrets when it is not desired to warm up the large compressors. There is no separate pump to supply the high-pressure air for the recoil service, but two plunger pumps forming parts of the large compressors supply the recoil cylinders. These pumps are thrown out of action by simply closing their suction valves.

The main compressors deliver air at 125 pounds per square inch gauge pressure. Although the recoil cylinders are surprisingly tight, yet after some months it is necessary to restore the working pressure in them, and, moreover, the guns are always secured for sea by being run in, which can be accomplished only by exhausting most of the air from the recoil cylinders. When the recoil service pressure is needed, the main compressor is started and the small plunger pump takes in air at 125 pounds pressure, delivering it at almost any pressure that may be desired. At present the working pressure in the recoil cylinders is 550 pounds per square inch. With this pressure the recoil of the 10-inch guns with full service charge, 240 pounds, of brown prismatic powder, is about 30 inches.

The recoil cylinders, two to each gun, are secured to the gun saddle. The pistons within the cylinders remain stationary; the cylinders recoil with the gun. The piston rods, which are secured to the rear transom of the carriage, are large and stiff, so large, in fact, that, with the air pressure the same on both sides of the piston, the gun is kept run out. When the gun is fired, there is, of course, a banking up of air before the pistons, but an ingenious valve rod, tapered in the middle, advances with each cylinder into the hollow piston rod and allows sufficient air to pass from one side of the piston to the other to restrain the rise of pressure within the desired limit. The valve rod is full at each end, so that a proper cushion is ensured at the limits of the recoil and of the counter recoil. The proper proportions of the valve rod were determined experimentally.

The action of the recoil mechanism is all that can be desired. The carriage and its pivots are not unduly strained, and the gun goes out to battery with a motion that is highly satisfactory. The firing of the guns does not necessitate repumping up the recoil cylinders, as the dense air is simply passed from one side of the recoil piston to the other. The maximum pressure in the recoil mechanism depends upon the taper of the valve rod, and never exceeds about 1350 pounds per square inch. The heavy piston rods of the recoil mechanism are packed with square machine-braided hemp, well soaked in paraffine. This packing is very efficient, and seems to last indefinitely.

All of the air supplied to the turrets is carried in two pipes, for the high-pressure and low-pressure services, respectively, to the central column. This column is provided with passages and leather packed sleeves that give the proper distribution to the various motors in the turret, undisturbed by its rotation. The train of the guns is 270 degrees, the superstructure on the deck of the ship preventing a complete rotation.

Two pipes are led along the sides of each gun carriage, one carrying air at 125 pounds pressure for the breech plug motor, the other supplying the recoil cylinders. The latter pipe is a small one, which leaves the carriage near its pivots and there takes the form of a flexible copper coil, which opens and closes as the gun is depressed or elevated.

The necessary flexibility for the low-service pipe is secured by employing a short length of hose such as is used in air-brake service. As the breech plug motor recoils with the gun, it is neces-

sary to employ a telescopic joint. The breech plug motor is simply a cylinder and piston, the latter attached to a stationary hollow rod, the cylinder carrying the tray which holds the plug itself. The telescopic rammer is carried on a heavy bracket attached to the gun carriage. It is always in line with the bore of the gun.

The weight of one of the *Terror's* 10-inch guns is 56,400 pounds, and the preponderance at the breech end is about 25,000 pounds. The ram which supports the rear transom of the carriage and determines the elevation of the gun is a simple hollow plunger, suitably packed, and bearing against the transom with its upper rounded head. In order to provide a dead beat movement for the elevating mechanism, the pneumatic system is combined with the hydraulic, that is, the fluid used under the elevating ram is a mixture of 80 per cent. glycerine and 20 per cent. water; and this liquid is fed to the elevating cylinder from a closed tank. The surface of the liquid in the tank is pressed upon by the air from the pneumatic valve of the elevating gear.

When the turret officer in the sighting hood moves the valve lever to secure the depression of the muzzle, two valves are moved by the one lever; one valve admits compressed air to the top of the tank, while the other admits the glycerine from the tank into the elevating cylinder. When the lever is thrown to mid-position, the elevating gear is locked, as the glycerine is inelastic. The other extreme throw of the lever allows the glycerine to exhaust back into the tank and the air from the upper portion of the tank to escape into the turret, the ram meanwhile falling as much as may be desired, and the breech of the gun following by virtue of the preponderance.

The magazine for each turret is located underneath that structure. Each gun has its own loading car, which moves up and down on a pair of curved tracks formed of steel Z bars. The movement of the car is imparted by a wire rope which leads over six multiplying sheaves mounted on the extremities of an upright cylinder and its ram. The shell is brought out from the shell room in tongs with trolley gear, and is then released into a tray, which swings it into position before the tray of the loading car. Pneumatic power is then applied to tilt the shell into the car. The powder, in two bags of 120 pounds each, is then placed by hand in the other trays of the car, which is now ready to rise. At the height of its travel the car strikes a lug on the bracket of the gun carriage, and has then assumed a position which brings the rammer, the shot, and the bore of the gun all in line. The rope of the car hoist reeves over a sheave on the gun pivot, so that the elevation of the gun, as well as the train, can be changed during the progress of the loading, without altering the relative positions of the rammer, loading car, and gun. This is a very happy arrangement and establishes the superiority of the *Terror's* turret gear over that found on ships fitted with hydraulic systems, where the guns usually have one or two loading positions to which they must return after each fire.

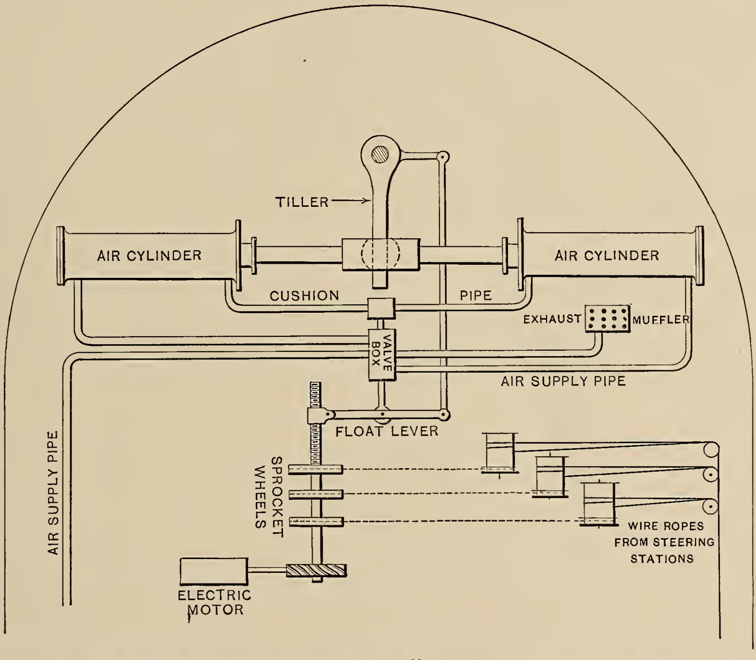
The turrets of the *Terror* weigh, with their contents, about 250 tons each. To turn this huge mass rapidly requires the exertion of a large amount of power for a short time. The friction is kept comparatively low by the employment of conical roller bearings. Nevertheless, to rotate the turret through its full train of 270 degrees in one minute, requires the exertion of several hundred horse-power during that brief period. The turret-turning gear consists of a couple of pairs of high-speed engines operating through worm gear and spur gear upon a circular rack fixed to the deck. The fineness of the gear is responsible for much loss of power through friction, but it is valuable in securing accuracy of train and dead beat movements.

The sequence of operations in firing and reloading one of the *Terror's* 10-inch guns is as follows:—Immediately after firing, the gun returns to battery without shock; a turn of a crank unlocks the breech plug; the rammer

reaches out, clasps the plug and withdraws it from the gun into the breech plug tray; the plug motor draws aside the plug; a jet of air plays for a short time into the open breech, driving out smoke and gases from the muzzle; the powder chamber is swabbed out; the loading car finishes its ascent; the rammer extends and drives the shot into the gun; the rammer returns; a catch is loosened and the first bag of powder drops into the tray just vacated by the shot; the powder is rammed home; the rammer returns and drives in the second bag of powder, which has been released into the tray; the rammer having closed up again, the breech plug slides into position; a stroke of the rammer drives the plug into the screw box, and, as the rammer again closes, a turn ot the crank rotates the plug through 60 degrees of arc and locks it. While all these operations have been going on, the gun has been laid upon the target. The electric primer is inserted in the breech plug and the gun is reported ready for firing.

As far as the actual movements of the mechanism are concerned, the actual time of loading, from fire to fire, is about 1 minute, 9 seconds; but the accumulation of powder ash becomes serious as the firing proceeds, so that good time for five successive rounds may be put down at about 13 minutes.

The pneumatic steering gear of the *Terror* is notable for its reserve power and for the simplicity of its mechanism. Two cylinders lie athwartship, facing each other and having a common piston rod. Only the outboard faces of the pistons are used to impart motion. The inner faces are much reduced in area by the large piston rod, and their effective area is utilised only in checking the motion of the piston rod. At the middle of its length this rod carries a slotted head fitted with circular brasses which move the tiller and at the same time allow its angularity to change. An ordinary *D*-slide-valve distributes the air for the motor. A certain quantity of air is confined in the inboard ends of the athwartship cylinders. This is the air for cushioning, and its elasticity and compressibility relieve the steering gear



THE PNEUMATIC STEERING GEAR ON THE MONITOR "TERROR" OF THE UNITED STATES NAVY.

from dangerous stresses likely to be engendered in a seaway.

A pipe which joins the inboard ends of the cylinders is fitted with a piston valve through which the cushion air must pass if it moves at all. The distributing slide valve and the cushion valve derive their motion simultaneously from a threaded spindle working in a nut mounted on a float lever. This float lever is connected on the same principle as similar levers in marine engine reversing gears. When the rudder moves in obedience to the air pressure in one of the cylinders, the motion is communicated to the float lever in such a way as to tend to close the distributing valve and the cushion valve. Thus any tendency to slamming of the rudder from one side to the other is avoided.

Rotary motion is communicated to the threaded valve spindle from various sources. There are steering stations in the ship's pilot house and also in each turret, and each of these stations is provided with both an electric and a mechanical steering device.

The mechanical devices are simply steering wheels carrying slender wire ropes to drums near the steering engine and communicating with the valve spindle through sprocket gear and toothed clutches. The electric device is ingenious A small motor is geared to the valve spindle with worm gearing. This motor is operated through rheostats, and is prevented from over-running,—when the helm is hard over,—by means of a cut-out. All sheaves used with the pneumatic machinery have ball bearings.

The use of compressed air on board ship is chiefly advantageous in that it affords a welcome relief from the heating effects due to the employment of steam for operating remote auxiliary machinery. Not only in time of battle, but during the long weeks and months that precede an action, the officers and crew suffer the evil effects of confinement below decks; and the warship which can most ameliorate the condition of her living and working spaces,—especially as regards temperature and purity of air,—stands the best chance, other things being equal, of flying her colours to the end of the fight.

THE DISTILLING SHIP "IRIS," FOR THE UNITED STATES FLEET.

By Passed Assistant Engineer W. W. White, U. S. N., Prize Essayist, American Society of Naval Engineers.

On the sea, as on the land, the present is the era of the engineer. Especially is this true of the whole fabric of naval war. From the dawn of history until, and beyond, the time when, under Cromwell, the British began their almost unbroken series of naval triumphs, the warrior afloat was, like Blake, a soldier simply. Time and the inevitable logic that the fighting man must know his ship, as well as his weapons, wrought such changes that in the days of Nelson and Collingwood, we find the sailor the supreme military authority. The soldier and the sailor have as their lineal successor in this age, the "fighting engineer." In giving this apt title to the naval combatant of our day, the Hon. Theodore Roosevelt, until recently the Assistant Secretary of the United States Navy, has said:—

"On the fighting ship, the fighting man must stand supreme; only he must know how to handle his tools and must change as the ship changes, so that precisely as he once knew about sails, now he must know about engines. There can be no divided command. Only one man can exercise it; but he must be thoroughly fitted for it."

The changes which time has made in the ship of the line and her lesser sisters, seem more like those of revolution than of evolution. In the old days, the needs of "the fleet in being" were few and simple. It could keep the sea indefinitely with little else than canvas, cordage, wood, oakum, and pitch for repairs; salt beef, hard bread, rum, and water for mess-supplies; and enough powder and round shot to equip the short and sightless smooth-bores, whose opposing muzzles almost touched in action before their fire became effective.

In this age of the engineer, however, old things have, indeed, passed away, and the warship has become a vast assemblage of mechanism—steam, electric, hydraulic, and pneumatic—whose requirements are as large and varied as those of a great engineering establishment on the land—with this vital difference, however, that to maintain, at a maximum, the fighting value of the modern fleet, its innumerable wants must be filled, whether it lie in the sheltered waters of a home port, or be in an alien and unfriendly harbour, thousands of miles from its nearest base of supplies.

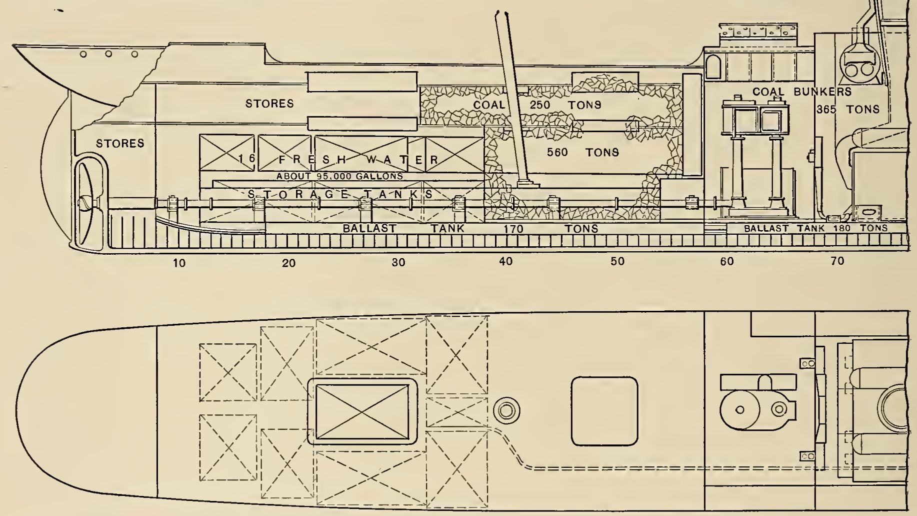
While steam holds its sway as the source of all the varied energies of a warship the fundamental needs of a fleet must be coal, and, with the intricate construction of modern boilers, an ample supply of fresh water. The absolute necessity of the latter, for boiler use, is a development of recent years, but follows as an essential condition of keeping the machinery, in its entirety, up to the highest pitch of efficiency. A solution of the problem has been admirably worked out by the United States Navy Department, in providing and equipping two distilling ships for the production and transport of fresh water, which vessels, in the auxiliary service of a modern war-fleet, are second only in importance to colliers.

While all modern men-of-war are fitted with appliances for making fresh from salt water, it is not always possible, owing to restrictions in space and

weight, to install either an economical plant or one of sufficient capacity for all purposes. In fact, it is only within the past few years that serious attention has been directed to providing a daily supply sufficient not only for drinking, cooking and incidental purposes, but also to replenish the inevitable waste in the feed water for the boilers. The universal practice previously had been to make up the loss of water, due to leakage in the various pipes, valves, etc., of marine machinery, directly from the sea, a course which had only simplicity to commend it.

With, however, the general introduction of triple expansion engines came the necessity of minimising scale in the boilers, not only on account of the liability to accidents, but, also, from the commercial requirement that increased life should be given the boilers, which, when constructed to withstand high pressures, were extremely expensive in first cost. It was realised, too, that the use of salt water, and the consequent formation of scale upon the heating surfaces, meant not only an increased expenditure of fuel under any circumstances, but as well, the impossibility for that reason of attaining the former maximum speed,—a factor which is of prime importance in a warship.

The introduction of coil, or tubulous, boilers has resulted in making the use of fresh water, not only desirable, but indispensable, if this type of generator is to be kept in efficient condition. Sea water is sometimes depended upon to make up deficiencies in the feed water with shell boilers, but it is resorted to only in dire necessity with coil boilers, where its frequent use never fails to produce disastrous results. Thus far, the tubulous type has generally been restricted, in the United States Navy, to torpedo-boats and destroyers; still, the numerous advantages which it presents, especially lightnes- as compared with shell boilers, has been a sufficient inducement to wars rant its installation as part of the boiler power in several cruising ships, and it is not improbable that, in the near future, shell boilers for naval vessels will be superseded by this type.



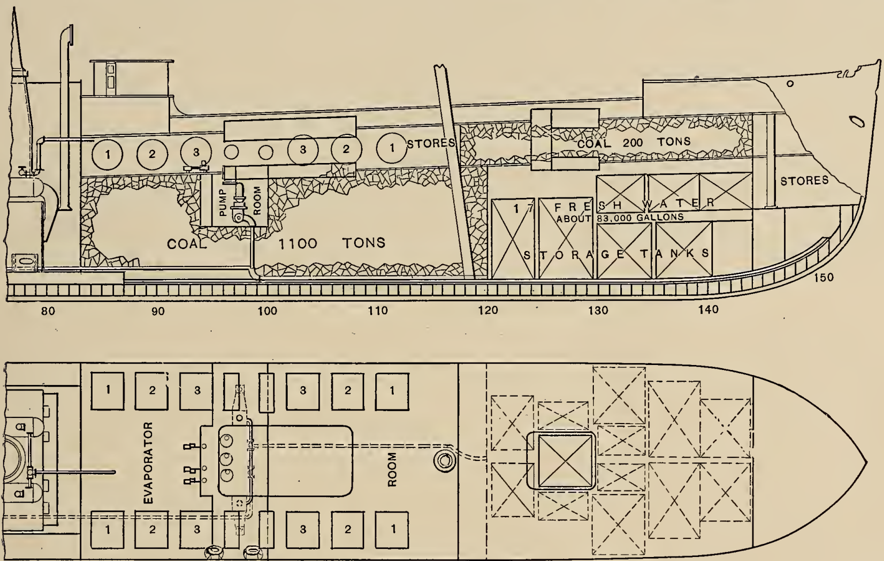
LONGITUDINAL SECTION AND PLAN OF THE UNITED STATES DISTILLING SHIP "IRIS."

An apparatus for the conversion of sea into fresh water becomes, therefore, a necessary auxiliary on all sea-going steamships. In its first stage of development the distiller assumed the elementary form of a nest of tubes, or coil, contained within an outer closed shell, sea water being continually circulated by a pump, or other means,

through, or on the outside of, the tubes, or coil, with a steam connection led directly from the boilers to the other side.

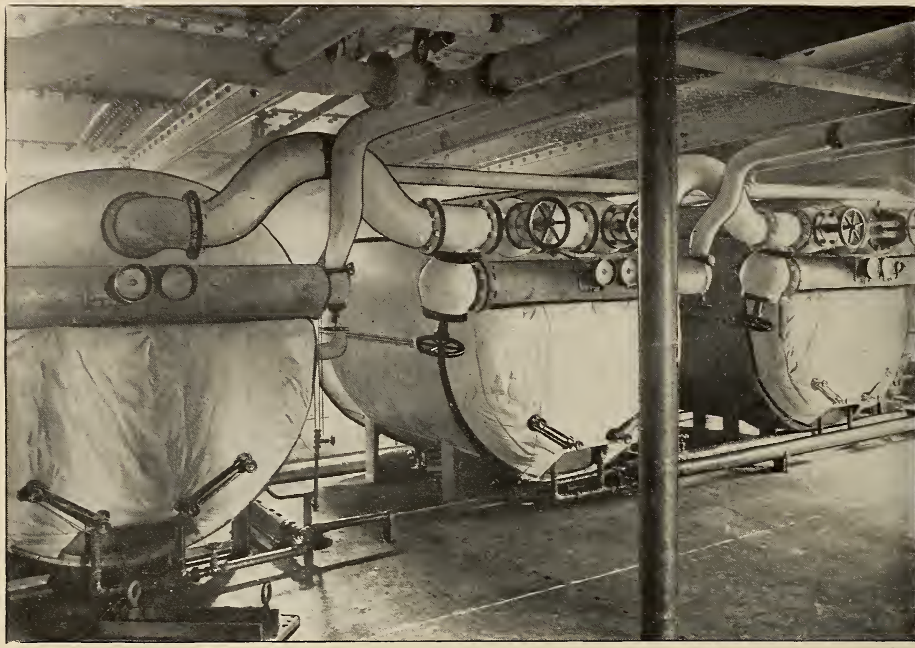
The circulating water, in removing heat, reduced the inflowing steam to water, which then dropped by gravity to storage tanks in the hold. This method possessed the salient fault of quickly causing the vital parts of the boilers to become coated with scale, since, as steam was condensed, its equivalent in volume of sea water had to be supplied to the steam generators, resulting in precipitation of certain salts on the internal surfaces, of which sulphate of lime is the most difficult to remove.

To obviate the formation and accumulation of scale in the boilers, evaporators are now generally installed and interposed between the boilers and distillers. For marine purposes, these consist essentially of a closed vessel containing sea water, in which heating surface in the form of a series of tubes, either straight, bent, or spiral, is disposed, and of a construction which permits the ready removal of the tubes for cleaning. While there is ample range for variation in the details of different designs, all are similar to the extent that steam originally from the boilers, in passing through the tubes, transfers heat to the surrounding sea water, and thus evaporates it into steam. This causes condensation in the tubes, and water so produced is finally returned to the boilers. Steam formed in the sea water compartment of the evaporator is piped to the distiller, and is there condensed, if it is intended for drinking purposes. If it is to be used to supply extra feed water for the boilers, any one of three courses, depending upon the arrangement of piping, is allowable, viz., directly to the main condenser; or to the low-pressure receiver of the engine to do useful work before condensation; or to the hot-well to mix and raise the temperature of other feed. Of these different arrangements of piping the latter is preferable from the standpoint of economy.



LONGITUDINAL SECTION AND PLAN OF THE UNITED STATES DISTILLING SHIP "IRIS."

The amount of "make-up feed" required is dependent, in a measure, on the power developed, the number of auxiliaries in use, the extent of steam piping and valves, and, above all, on the care exercised in preventing waste. Generally speaking, it may be taken as from 6 to 8 tons per day per 1000 I. H. P. developed.



A SET OF THREE EVAPORATORS.

Complication, weight, and space limit the choice of evaporators for warships to the single-effect system,—the apparatus just described,—and this type of plant is the only one installed on these vessels. It is usually of sufficient capacity to furnish the extra feed needed for ordinary cruising, but is totally inadequate for extended steaming at high powers.

It is customary, therefore, to carry in the double bottoms a reserve supply of fresh water for boiler use, procured from the shore. But when a squadron is actively and continuously engaged at considerable distance from a base where fresh water is to be had in quantity, economical distilling ships of great capacity, to follow and supply the different ships as required, become an imperative adjunct to the highest efficiency. To meet the exigency thus developed in the recent war between the United States and Spain, the United States Navy Department, on the recommendation of Commodore George W. Melville, the engineer-in-chief of the Navy, some time ago purchased and fitted out two distilling ships, the *Iris*, formerly the *Menemsha*, of the Hogan Line, and the *Rainbow*, late the *Norse King*. The distilling plants of both are the same in all principal parts, differing only in slight details. The particulars of one, therefore, answer practically for both. It is to the *Iris*, however, as having been the first of the two to go into commission, and the first vessel of her kind in the world, that this description relates.

It is evident that the controlling element in the design of a large distilling plant, for the purposes mentioned, is, of necessity, economy in expenditure of fuel, and to insure success in this direction a sufficient allowance of space and weight is essential. As an assurance of economy, multiple evaporators, working in series, are installed, by which means steam, generated in the first, or high-pressure evaporator, is utilised to generate steam in the second, or intermediate, and steam from the latter, passing to the third, or low-pressure, produces steam which is finally sent to a condenser. It will be observed

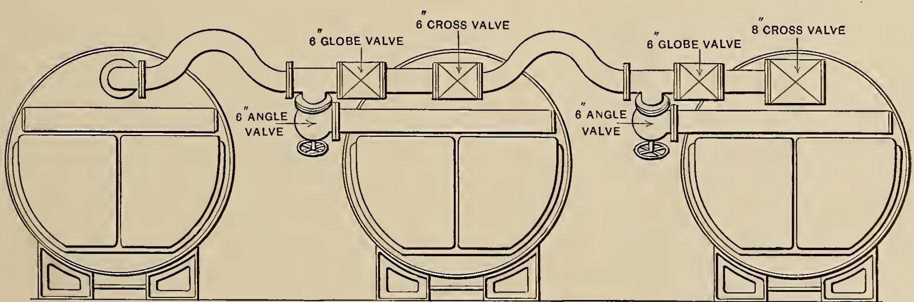
that boiler steam is used only in the tubes of the first evaporator.

The *Iris* is an iron vessel, 310 feet between perpendiculars, 38½ feet beam, and 27 feet depth of hold. Her main machinery, which was built in 1885 by Messrs. R. & W. Hawthorn at Newcastle-on-Tyne, England, consists of a compound engine with cylinder diameters of 31 and 70 inches and a common stroke of 48 inches, with two cylindrical double-ended Scotch boilers, each 12 feet in diameter and 16 feet long, containing four plain furnaces of 42 inches diameter. A horizontal steam drum is provided for each boiler. The grate and heating surfaces are, respectively, 154 and 5114 square feet.

The speed of the vessel when loaded is about 10 knots, and is from 11 to 12 when light, the I. H. P. varying between 1300 to 1400. Her coal bunker capacity amounts in all to about 2475 tons.

The distilling plant was designed by the Bureau of Steam Engineering, United States Navy Department, was built by M. T. Davidson, of Brooklyn, N. Y., and was installed at the Navy Yard at Norfolk, Va. It consists of 12 cylindrical evaporators, alike in all particulars, 5 feet, 6 inches in diameter by 6 feet, 2½ inches in length, arranged in four groups of three each. The total daily capacity, when working in triple effect, is calculated to be 60,000 gallons, and for each pound of coal burned in the boilers an approximate output of two gallons of fresh water is expected. While it is contemplated, under ordinary conditions, that the plant shall be worked on the most economical basis, yet provision has been made in the design for great elasticity. To this end, the piping between the evaporators of each set is so arranged that the three of each group may be worked in triple effect; or, with any one of a set cut out, the remaining two may be worked in double effect; or, so that all may be used in single effect. Moreover, as each of the evaporator coils is divided into two equal nests for convenience in handling, when withdrawn for cleaning or repairs, blank bonnets are provided, so that, in such an event, the half remaining in place may continue in use.

The shells and heads of the evaporators are of steel, ½ inch thick, and designed for a working pressure of 50 pounds. In proportioning the water liberating surface and steam room, sufficient was allowed to insure dry steam when working under a vacuum of 24 inches, with an output from each evaporator of 4000 gallons, these being approximately the limiting conditions of the low-pressure evaporator in triple effect. One manhole, 11 × 15 inches, and a cleaning hole 6 × 6 inches, are provided in each shell.



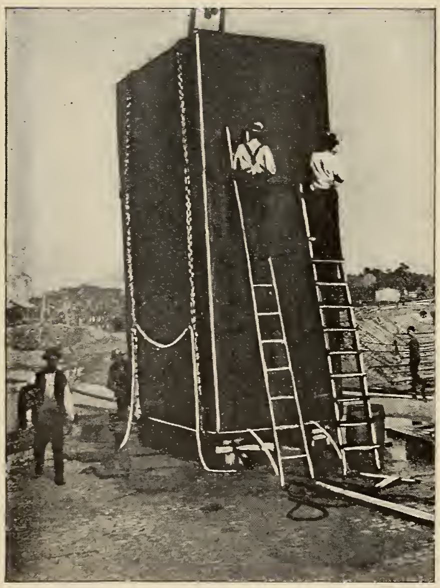
ELEVATION OF ONE GROUP OF EVAPORATORS, SHOWING STEAM PIPING ARRANGED SO THAT EVAPORATORS MAY WORK IN SINGLE, DOUBLE OR TRIPLE EFFECT.

Each evaporator is provided with two manifolds, fitted with straight brass tubes, 2 inches outside diameter, tinned inside and out, No. 13 B. W. G. thick, with a total heating surface of 320 square feet. The tubes are expanded into steel tube-sheets, the inner one of which, together with its chest, is free to move in order to provide for

expansion. Steam chests and bonnets are of cast iron, and these parts and the tubes were tested to a pressure of 150 pounds per square inch.

Four condensers, one for each group of evaporators, are a part of the installation. They each contain about 300 square feet of cooling surface in the form of brass tubes, 5/8 inches outside diameter and No. 18 B. W. G. thick. Sea water is forced through the tubes, and the resulting condensed or distilled water on the outside of the tubes is removed and sent to an 8-inch main, with branches to different storage tanks in the hold by 6″ × 8″ × 10″ single-cylinder air pumps, situated directly beneath each condenser.

For circulating sea water through the condensers, two 10″ × 14″ × 14″ single-cylinder pumps are provided, and the arrangement of piping and valves is such that either pump and any condenser may be shut off for overhauling without interfering with the operation of the remaining part of the plant. These pumps are also intended for transferring fresh water from the storage tanks to ships alongside, and either may be used for this purpose while the other is in operation, circulating sea water through the condensers.



ONE OF THE THIRTY-SIX TANKS PLACED IN THE FORWARD AND AFTER HOLDS FOR STORING DISTILLED WATER.

When used for discharging fresh water, the suction is taken through a pipe joining the distributing main to the storage tanks, previously mentioned, and in this suction two valves are placed, back to back, to minimise the chances of salt water mixing with the fresh. The discharge, under these circumstances, leads to a manifold, fitted with proper valves and 2½-inch hose connections, on the upper deck.

Three feed heaters, having about 50 square feet of heating surface each, are operated in conjunction with the plant, the heating agent being the exhaust steam from the various pumps and the water drained from the evaporator tubes. By this means considerable saving in heat-units results from the temperature of the sea water being raised before entering the evaporators to be converted into steam.

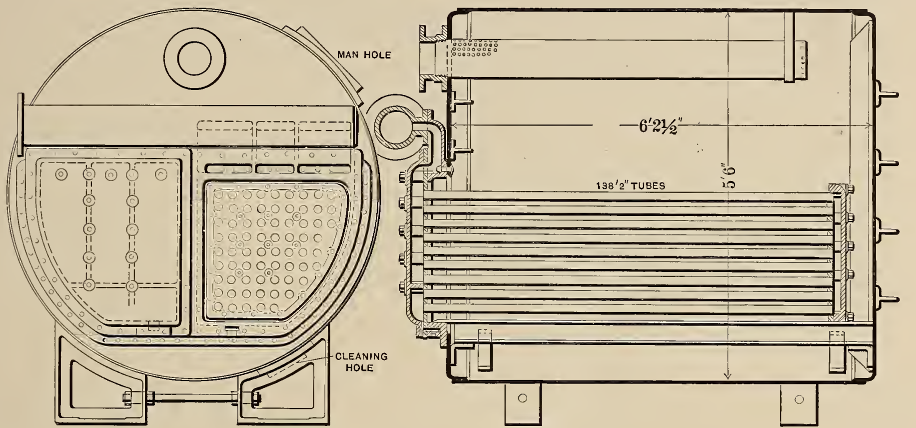
It is obviously desirable, in the practical operation of the plant, that steam generated in the boilers, or water resulting from the condensation of such steam, should be kept entirely distinct from steam or fresh water produced by the evaporators. This separation presents no difficulty other than an apparent complication of piping and valves about the feed heaters. Ordinarily, two of these are employed in raising the temperature of the sea water feeding the evaporators, heat being abstracted for the purpose from the exhaust steam of the different pumps and from the water discharged from the traps draining the tubes of the first, or high-pressure, evaporators; in other words, by steam taken in the first instance from the boilers, and which, after condensation, drops through gravity to the feed tank, to be returned to the boilers as feed water.

The remaining heater, which is fitted for the same purpose as mentioned for the other two, utilises as a heating agent the drain water from all evaporators except the high-pressures. The first-mentioned drains form part of the out-

put of distilled water, and, in consequence, after transit through the heater, pass to the condensers of the plant. The arrangement of piping, valves, etc., also permits all exhaust steam, and trap discharges from the high-pressure evaporator tubes, to be sent directly to the main condenser, or feed tank, in the engine room.

For supplying sea water to the evaporators, three single-cylinder pumps, 6″ × 4″ × 8″, are provided, which draw from the overboard delivery pipes of the condensers, and are so arranged that any pump may feed any evaporator, either direct or through the feed heaters. Provision is also made by which the evaporators working under a vacuum may be fed by gravity. With the entire plant in operation, however, it is intended that each pump, feeding through a feed heater, shall supply each group, or lot, of evaporators (high-pressure, intermediate, and low-pressure) which work at the same pressure.

As water in the different evaporators becomes concentrated from the continuous generation of steam and constant substitution of sea water therefor, connections by which the saturation may be reduced after reaching a prescribed limit, are necessary. Two brine pumps, of the same size as the feed pumps, one for each set of six evaporators, are installed for this service. By-pass pipes and valves between the suction and discharge pipes are fitted, in order that those evaporators under pressure, exceeding atmospheric, may be blown down without other resource.

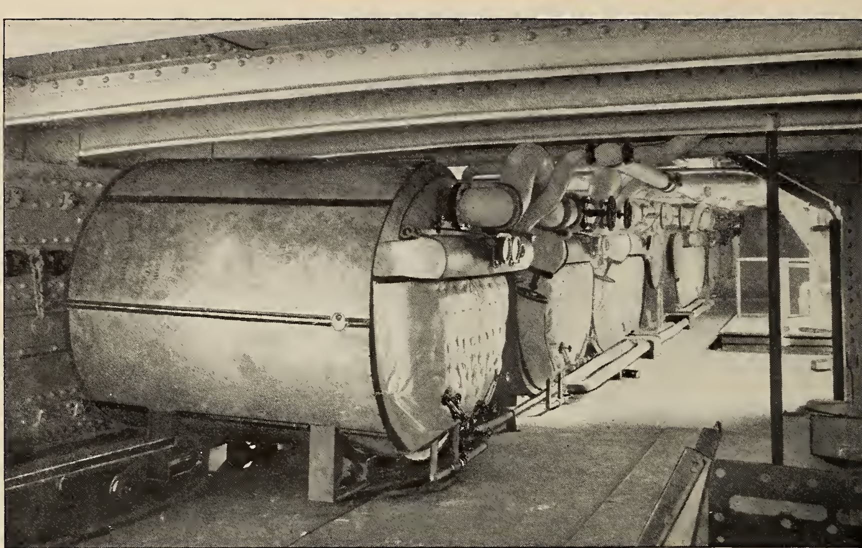


ELEVATION AND LONGITUDINAL SECTION OF ONE OF THE EVAPORATORS.

Salinometer pots are fitted to all evaporators for the purpose of ascertaining the density of the contained water. Usually, sea water has a density of 1-32, as compared with distilled water; or, in other words, the different salts dissolved amount to about 1-32 by weight, of which nearly 4-5 is common salt. With the plant in operation, the brine pumps serve to maintain the saturation at about 3.5-32 in the low-pressure evaporators, a density which experience has proven should not, as a rule, be exceeded. These pumps may also be used, if desirable, to remove water from any of the evaporators.

The tubes of each evaporator are drained by traps, which act automatically, as water accumulates from the condensation of the entering steam. Two mains are installed to receive the discharge from these, with valves to direct the flow to either. One main joins the exhaust pipe from the pumps, while the other is led into one of the feed heaters.

In designing the various details of the plant care was observed in so propor-



THE STARBOARD SIDE OF THE EVAPORATOR ROOM.

tioning those parts which require removal for periodic cleaning that they might be readily handled by ordinary appliances, and without necessitating the breaking of pipe connections. Attention was also given to accessibility of parts so removed, and facility of repair or renewal of any element in case of injury. Special tools, used in assembling the different details, are furnished as part of the outfit.

The steam pipes are of such size that the velocity through them does not exceed 7000 feet per minute under maximum conditions of output, and all steam and exhaust piping is seamless drawn,—of copper, where the diameter is of 2 inches or above, and of copper or brass for sizes below. All piping through which distilled water is conveyed, is of iron. Steam and exhaust piping, evaporators, heaters, etc., are carefully lagged and covered to prevent radiation.

In the operation of the plant it is intended to maintain boiler pressure, or 110 pounds, in the first evaporator tubes. The resulting shell pressure, and pressure, consequently, in the tubes of the second, or intermediate evaporator, is to be 30 pounds. This will produce a shell pressure in that evaporator, and pressure in the tubes of the last evaporator of 16 pounds, steam being finally generated in the low-pressure shell under a vacuum of 24 inches and sent to the condenser. The pressures given are absolute.

Assuming the heat communicated to the sea water, in passing through the feed heaters on its way to the different evaporators, to be sufficient to raise the temperature to 212 degrees, one pound of boiler steam will cause the generation of 0.9 pounds of steam in the shell of the high-pressure evaporator. This produces 0.87 pound of steam in the shell of the intermediate, and the latter, in turn, evaporates 0.88 pound in the shell of the low-pressure. At the expense of one pound of boiler steam, therefore, 2.65 pounds of distilled water are obtained when working in triple effect. This figure, however, must be reduced by loss due to "brining," which amounts for all evaporators in the present case, to about 5 per cent., decreasing the net result to 2.52.

The total average I. H. P. of the eleven pumps, run in connection with the evaporators, and of the feed pump operated to supply the boilers, will be about 20. Allowing an average steam consumption per hour per I. H. P. of

*150 pounds for these various pumps, the total daily expenditure of steam for this purpose is 72,000 pounds. An output of 60,000 gallons of distilled water demands 198,413 pounds of boiler steam, and assuming a loss due to radiation and condensation of 2 per cent., the total steam required per day to operate the plant is 275,921 pounds.

As the feed water is returned to the boilers at a comparatively high temperature, an evaporation of about 9 pounds of water per pound of coal, at the pressure used, may be expected. This results in a daily expenditure of 13.69 tons of fuel, each pound of which produces 16.3 pounds of water. Considering the average cost of coal to be $3 per ton, each ton of distilled water is obtained for 18 cents.

The cost of fresh water in different ports varies considerably; 70 cents per ton is not far from the average. Such water generally contains impurities, and, in addition, is usually put on board ships from lighters, slowly, with difficulty, and inconvenience. The *Iris*, being fitted with every facility, is enabled, not only to supply all demands with dispatch, but at about one-quarter the outlay.

The problem of furnishing fresh water in quantity to warships at sea is but one of many which have confronted the United States Navy Department in the recent war with Spain. The nation which was the last to provide itself with a modern fleet has been fated to be the first to face the task of supplying that fleet in action, at a distance from home-shores. That this has been done effectively the world has seen in the notable work of American squadrons off the coast of Cuba and in Manila bay.

*This figure is somewhat larger than the usual engineering practice allows; but the writer believes it to be fully sustained by careful experiments made by himself and others on auxiliary machinery, the results of which tests are given in a paper entitled "Steam Consumption of the Main and Auxiliary Machinery of the U. S. S. *Minneapolis*," published in The Journal of the American Society of Naval Engineers, Volume X., No. 1.

Current Topics.

FOR many years steam jets have been considered excellent means for extinguishing fires in inclosed spaces, and examples of their good services have been abundant. The theory of their action, of course, is, like that of the several kinds of fire-extinguishing powders which have been proposed at different times, that the steam in the one case, and the stifling fumes from the powders in the other, displace the air in any particular space under consideration, and, with it, the oxygen as well, by which alone combustion can be sustained. In at least one instance, however, the position was taken that if the steam jets did not extinguish a fire promptly, they soon became a source of danger, and, as such, were held accountable for the loss, about a year ago, of a cargo steamer carrying several hundred tons of coal and as many more of miscellaneous chemicals and old rope. Fire broke out in one of the holds, which were fitted with steam jet fixtures, and the jets were at once turned on. On the day following it was proposed to try a hose, in addition to the jets, and one of the upper deck hatches was, therefore, taken off. The almost immediate result was a violent explosion, killing one of the officers and seriously injuring another. All the other hatches were blown off at the same time and the ship began to leak, so that she soon had to be abandoned. One explanation advanced was that the steam from the jets, passing over the incandescent cargo, formed water-gas, which, with suitable air admixture, became explosive, with the result noted. The theory is not a comforting one, but whether it portrays a possible condition of things yet remains to be demonstrated.

INSTEAD of steam, or other usual fire-extinguishing agents, liquid carbonic acid gas, discharged into ships' holds or other spaces through pipe systems, was proposed several years ago by Professor R. Ogden Doremus, of New York. The Board of Marine Underwriters, of New York, is said to have once reported favourably on the plan, but nothing further ever was done with the suggestion. Fire, of course, cannot maintain itself where there is a sufficient quantity of carbonic acid, and Professor Doremus' plan of simply having a stop-cock to turn, so as to let the gas escape from the pipes into any compartment on fire, seemed to have all the merits of simplicity and effectiveness. An 8-inch steel cylinder, 5 or 6 feet long, would hold enough liquid carbonic acid to fill a very large space with

sufficient gas to put out a fire. The cost of equipment and maintenance, too, would not be great, and even if it did run up to a figure of some magnitude, it would probably represent but an insignificant proportion of the saving which the method might effect.

In connection with the article in this issue concerning mechanical draught for steam boilers, it is worth calling particular attention to the illustration on page 50, which helps to tell an interesting story by the B. F. Sturtevant Company, of Boston. The enlargement, some time ago, of the works of the company, at Jamaica Plain, Mass., necessitated the removal of the boiler plant to a new location, and the abandonment of the existing chimney. Instead of building another chimney, a fan was installed immediately above the battery of boilers, as shown in the cut. This fan, which, by the way, thus occupies no floor space, operates on the induced system; the gases pass directly to it from the uptake and are discharged through a short stack extending just through the roof of the boiler house. There is no smoke, and the engine speed is automatically controlled so that a very slight drop in steam pressure greatly increases the intensity of the draught The steam pressure is thus maintained absolutely constant. With the chimney it was necessary to burn Cumberland coal costing $3.65 per ton. Now it is possible to utilise clear yard screenings costing only $2 per ton. Comparative tests showed an evaporation of 10.1 pounds of water from and at 212 degrees F. per pound of Cumberland coal, and 9.28 pounds per pound of a half-and-half mixture of Cumberland and screenings costing $2.85 per ton. On this basis, and under the best conditions of coal consumption, the annual fuel expense would be:—

Cumberland	$5,929
Mixture	4,995
Saving	$ 934

The fuel cost of operating the fan is practically nothing, for the exhaust steam from the fan engine is utilised for heating, and the fuel saving in a single year is greater than the first cost of the mechanical draught plant. This cost was less than half that of a chimney. A combustion rate of 21.45 pounds of coal per square foot of grate per hour was maintained, and the horse-power was increased 103 per cent. above the rating, with an evaporation of 10.75 pounds of water from and at 212° per pound of combustible and a temperature at the fan inlet of 389.5°. Had the size of the plant warranted the use of an economiser, this waste heat might have been utilised without impairing the draught. After two years' continuous use of the fan without perceptible depreciation, the absolute uselessness of the chimney became so evident that it was recently taken down for the sake of the bricks it contained, and the passer-by now queries as to the method of draught production employed in a large manufactory without a chimney.

One of the features of machine tools of American make, which almost invariably elicits favourable comment in other countries, is handiness. It is not that the American workman is essentially a creature of comfort, which has inspired constant seeking after conveniences, but the striving for economy in methods, if not in processes, and for saving in time, is characteristic of American ways of doing things, and has ultimately left its impress on the work of the designer of machinery. Precedent counts less with him probably than with most designers of other nationalities; it is the new, the untried, but possibly useful, which appeals to him for experiment, and the outcome of his enterprise has materialised in many little labour-saving details which have helped to make an enviable reputation for the output of the American tool builder. British builders, and those on the Continent, as well, for that matter, are rather apt to disregard conveniences, and handiness in machine

tools frequently receives too little consideration from them. In one instance, cited recently, an establishment was visited where some large drilling machines, made by a very well-known firm, were in use, and in which the various handles and levers were particularly well arranged. Remark concerning them brought out the statement that it was only after insisting on that arrangement, and absolutely refusing to accept the machines until they were put right, that the desirable points were gained by the purchasers. Little doubt was expressed, however, that the makers did not profit by the hint, but still continue to make the machine for others in the old style, although the improvement demanded could not fail to be evident to all users. Conservatism of this kind does not lead to a useful purpose.

One of the most interesting contributions to the already extensive literature on painting iron and steel has just been made in the shape of a booklet, entitled "Painting to Prevent Corrosion. With Specifications. By A. H. Sabin, M. S." In a certain sense it may be considered a trade publication, inasmuch as it is published by Messrs. Edward Smith & Co., of New York, manufacturers of a special kind of protective coating for metals, and, besides, advocates the use of this coating; and yet it contains so much of general value concerning the subject that every engineer will profit by carefully going over its pages. One of the points upon which the author dwells with particular emphasis, and which, indeed, is at the bottom of all protective metal-work coating worthy of the name, is the thorough preparation of the surface of the metal before painting, and there certainly ought to be hearty concurrence among engineers in his opinion that better and more conscientious *methods* of painting are needed far more than any new and improved kind of paint. In other words, a comparatively poor paint, properly applied to a good surface, is better than a good paint on a poor surface. More than a century ago that eminent engineer, Smeaton, observed that when iron once has rusted, so as to have acquired a scale, the rust will go on progressively under any coat of paint or varnish that may be put over it. A century of observation and experience has called for no change in this remark, and the thing, therefore, to decide is how to get the desired surface. The cleaning of structural metal by the use of the sand blast, or by pickling in acid, is accordingly taken up by the author in the opening section of his little treatise, and the conscientious observance of the recommendations which he makes under these heads would, in itself, accomplish more than the indifferent application of the best metal coating that has yet been put on the market.

About the only good reason that exists to-day for building a cable tramway in preference to one operated electrically is heavy grades, extraordinary heavy grades, in fact, and many cable roads now operating are practically relics of obsolete engineering practice. Indeed, in the case of one of the two large cable roads in the city of New York the work of transformation into an electric road with underground conductor is now actively going on, the experience with the open-conduit electric-traction system having been wholly satisfactory even there where a few years ago exceptional difficulties for this type of tramway were expected to result from unclean streets. The other tramway company will probably commence similar construction work in the near future. In the light of such experience cable-tramway building under ordinary conditions seems a bit antiquated, and even the almost all-pervading overhead electric trolley is in prospective danger of being ousted, at least from big towns where the traffic returns are heavy enough to warrant the demand upon the companies to adopt the conduit construction. In small places the insistence upon this form would almost certainly bring financial disaster to the compa-

nies, owing to the necessarily high cost of rebuilding the lines, and it is therefore, most unlikely for the authorities to exercise what right may be theirs. It is a pleasing reflection, however, that underground electric trolley systems, so-called, or, more properly, open-conduit systems, have shown themselves, beyond all doubt, to be practically successful, and, in large cities, profitable investments of the first order.

A VERY interesting case, involving the question of damage to shipping by galvanic action, was recently fought before the Italian law courts. From the account given in *The Engineer*, it appears that the captain of the port of Leghorn, Cavaliere Alcesti Torrini, was the plaintiff in an action against the owners of certain wooden yachts with coppered bottoms, lying in the Darsena part of the harbour of Leghorn, to enforce a notice on the owners for the removal of such vessels from that part of the harbour. This notice was made on the grounds that the new warships and other iron and steel vessels lying in that part of the harbour were damaged by galvanic currents set up from the copper bottoms of the wooden yachts, the contact with the steel vessels being due to ropes which were made fast to different buoys in the harbour or basin. The fact of the damage to steel and iron ships having arisen and of its being due to this cause was clearly established before the court, and the captain's orders for the removal of the wooden yachts with coppered bottoms from the Darsena harbour of Leghorn was consequently confirmed by the court.

PROFESSOR VIVIAN B. LEWES, in a paper read before the Institution of Naval Architects some years ago, stated that damage to shipping was liable to arise from such a cause; and he also put forward the same theory in his book, "Service Chemistry." The fact of the existence of such a danger must be known to very few shipowners, but it is quite possible that the not infrequent phenomenon of an abnormally rusty bottom of some steel ship might be traced to her having been in galvanic contact with some copper-sheathed wooden vessel. But it is stated in *Fairplay* that in Italy there is another cause for damage at work, which is not unlikely to manifest itself before long, in so far as several anti-fouling compositions manufactured in Italy rely for their anti-fouling effect solely upon the presence of a very large percentage—30 to 40 per cent.—of metallic copper. Such compositions are applied to the bottoms of a large number of Italian ships, in conjunction with a coat of priming which is supposed to serve as an insulating medium. However effective powdered copper may be as an anti-fouling medium, it is believed that it cannot be applied with impunity to iron and steel ships. In England anti-fouling paints containing metallic copper are also made, but in no case are they applied to iron or steel ships; they are used only for wooden ships, such as fishing vessels and wooden trawlers, on which they give good results; but manufacturers of compositions in Great Britain who supply iron and steel ships have long realised that paints containing metallic copper are absolutely unsuitable for application on steel vessels, a fact on which Professor Vivian B. Lewes expatiated in his book referred to.

EVEN if insulated to some extent by a coat of priming paint from the outer surface of the vessel's plates, the presence of 30 to 40 per cent. metallic copper in a paint exposed to the action of salt water must set up a strong galvanic action in the whole structure of the ship, and this cannot fail to exhaust itself on those parts of her structure which are most exposed to corrosion or least protected against it; for instance, the floor plates, tank bearers, tank tops, bunkers, etc., for the galvanic current produced on the outside surface fills the whole metal structure of the ship, and whichever plates are most susceptible to corrosion through exposure or otherwise, will be most attacked by it. For reasons of cheapness paints so manufac-

tured have, during the last year or two, been largely used by Italian shipowners, and have even been applied to several mail and passenger steamers, on which they are undoubtedly a source of great danger to life and property. No doubt Italian shipowners who have indulged in such false economy will, when passing their vessels through their periodical surveys, pay a bitter penalty for their ignorance and parsimonious practices. In the meantime shipowners should be warned against accepting any anti-fouling paints in Italian ports, without a guarantee that they are free from metallic copper.

WHILE it has happened several times in years gone by that, through accident in design, vessels were built with more beam on one side of the centre line of keel than on the other, making them lop-sided, it remained for a board of United States naval constructors, away back in the forties, to intentionally locate the propeller shaft of one of the United States vessels off to one side of the keel, and that by as much as 20 inches. Passed Assistant Engineer F. M. Bennett, U. S. N., writing of this vessel,—the cruiser *San Jacinto*, by the way,—in his interesting book on "The Steam Navy of the United States," says that three of the members of the board that settled upon the plans, while eminent in the business of ship designing and building, were new in experience with screw-propelled ships, and they could not bring themselves to agree to any application of steam power that involved cutting a big hole for a shaft through the stern-post. Nothing apparently would do but locate the propeller shaft in the specified odd position, and this entailed its projection far enough beyond the stern to allow the screw to work abaft the rudder. The crew itself, as designed, was a ponderous six-bladed affair, weighing about seven tons, and this weight, overhanging the stern five feet at least, was manifestly a menace to the safety of the ship. The whole arrangement was very properly condemned by a board of engineer officers appointed to examine the *San Jacinto* and her machinery, and rational changes were recommended. The propeller was altered accordingly, but the shaft passage through the stern having been cut, the recommendation of the board regarding its modifications was not carried out.

IT is worth bearing in mind by engineers in charge of refrigerating plants that leaks in the ammonia coils of a brine tank cannot ordinarily be located by putting these coils under a heavy ammonia gas pressure with the expectation of seeing gas bubbles coming from where the leak might be. Unless the leak be a very large one, the escaping gas would be almost instantly absorbed by the surrounding water or brine, and there would be no rising of bubbles to the surface of the tank. Probably the best method of detecting such a leak, recommended by *Ice and Refrigeration* in response to a correspondent's inquiry, is to put the coil under a good high pressure, first pumping all the ammonia out of the coil. The air bubbles coming from the leak will then very clearly indicate where the trouble is to be found.

AT least one American railroad company,—the Santa Fé,—is said to have made arrangements to light all the cars of its limited trains running between Chicago and Los Angeles, a distance of 2209 miles, with electricity generated from the car axles. The electric equipment of each train will aggregate 4928 candle power. All berths will be provided with berth lights, and this will probably be the first train in the world carrying such a large supply of light service exclusively from the car axles. It is the intention also to light the locomotive headlight from the same service, thus making these trains solid axle-light trains throughout. The introduction of this system on the limited trains will mark quite a departure from previous practice, which necessitated a lighting plant in the baggage car. Each car of the train will have its own plant, comprising a dynamo and storage batteries.

FROM A PHOTO BY DAVIS & SANFORD, NEW YORK

Henry R. Towne

PAST PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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LUXURY IN AMERICAN RAILWAY TRAVEL

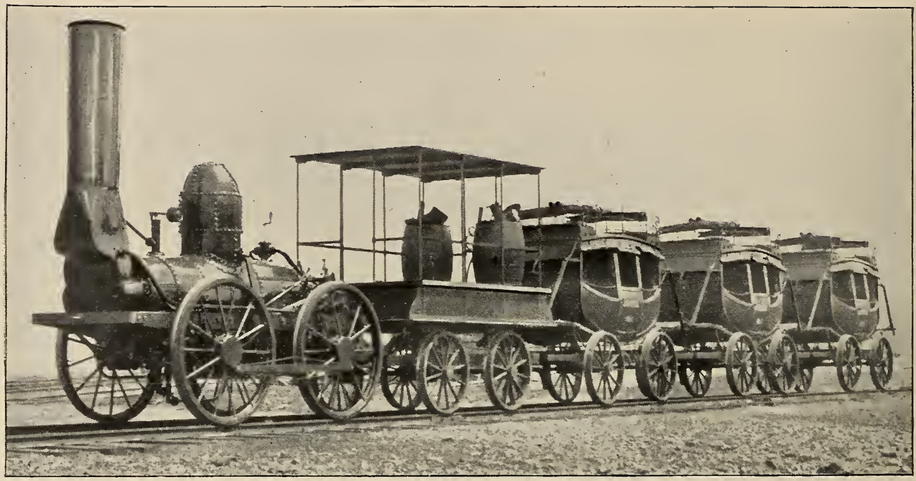
By Frank J. Bramhall

COMFORT and luxury are largely relative terms. Our forefathers thought they had reached the acme of comfort and even of luxury in travel when the fast mail coaches were run between London and the provincial towns, and yet their descendants would consider it a great hardship to travel as they did.

The confinement to a single place in, or on top of, a stage-coach, to travel over roads not always macadamised or paved, frequently snow-bound in winter, and water-bound by the floods of spring, struggling through, or stuck in, bogs or bottomless mud, and halting at irregular times for such refreshments as the wayside inns afforded, while a diversion that might afford pleasurable recollections, is not a method of travel that commends itself to the traveller of to-day, who expects, by steamer or by rail, the highest degree of speed attainable, combined with the utmost comfort of body, and relief of mental apprehension or strain.

When the first railroads were built, the Liverpool and Manchester, in England, and the Mohawk and Hudson, in America, the coaches were smaller in almost all details of construction than those drawn by horses,—and, indeed, the first that ran out of Baltimore and out of Charleston, in the United States, were drawn by horses, though the flanged wheels ran upon rails. Gradually, as the primitive methods were improved and outgrown, with the increase in weight of the rails and solidity of roadbed, there was an increase of weight, solidity and strength of locomotives and of cars.

It was several years, however, before the stage-coach model of construction was succeeded in America by the long coach which is the modern type. In Great Britain and on the Continent of Europe the interior arrangements and construction of the railway coaches preserve the character of the old stage-coach, or a combination of three or more of the latter, the coach being divided into compartments of the width of the car, and containing two seats facing each other, the doors of entrance, containing the windows, being upon either side. These compartments are of three, and sometimes four classes, the first being as luxurious as cushions



THE "DE WITT CLINTON" HAULING A TRAIN ON THE NEW YORK CENTRAL RAILROAD IN 1831

AN EARLY AMERICAN SLEEPING-CAR

and hangings can make them, whilst the third and fourth-class compartments are bare and comparatively comfortless.

In America, the corridor coach, as it would be called in Great Britain, has always been, and still remains, the popular and most practical form,—a long car with a middle aisle, seats upon either side, and doors at each end, opening upon platforms, and thus admitting of communication from one end of the train to the other. The long coach was originally placed upon two trucks or bogies, with pivotal connections, adapting them to the sharp curves of the road. These trucks, at first with two wheels each, were later provided with four wheels with the increased length and weight of the coach, and at the present day six-wheeled trucks are by no means uncommon. These and other features of construction that accompanied them added greatly to the comfort of the passenger, by enabling greater speed to be made with increased steadiness and smoothness, and a comfortable freedom from jars, jolts and oscillation.

Contributing to the same result were practically all the improvements in railroad construction during the last half century. The shape and weight of the rail, the relative position of joints, the application of fish bolts, the increased weight of cars and trains, as well as improvements in spark arresters on the engine, screens and ventilators in the coaches, the successive substitutions of oil lamps, gas, Pintsch light, and electricity for the original tallow candle, the improvement in heating apparatus, the adoption of air brakes, and a score of other devices, not only added to the safety of the passenger, but also to his physical comfort and the agreeableness of his journey.

So far as the eye can see,—at least the untrained eye of the average passenger,—fifty years have wrought little change in the American railroad passenger coach, excepting that it is manifestly longer, larger, heavier, more elegant in its cabinet work and decorations, with softer cushions and better adjusted seats, and, upon a few of the principal roads, the addition of that exceeding comfort, if not luxury to the weary and dust-stained traveller in summer, a convenient lavatory, with all the necessary toilet appliances.

A TYPICAL MODERN PULLMAN DRAWING-ROOM CAR

The most marked feature to be seen

A DAY-TIME VIEW IN A MODERN SLEEPING-CAR

in a survey of the progress and improvement in railway travel is the sleeping car, marking a sudden and great advance in the comfort and luxury of travel. It was quite natural that so wonderful an improvement in railroad service should have been devised and executed in America, where, indeed, most of the improvements in railroad service have been made, for it grew out of the natural demand created by the long distances which the traveller was frequently obliged to traverse, involving continuous travel by night as well as by day. The comparatively short distances of travel in Europe produced no such demand until after America had demonstrated the great utility of the device, and the extension of railway lines in Europe upon uniform gauges made such a service practicable.

When, in the United States, the railroad was first completed to Buffalo, on Lake Erie, the line from New York or from Boston consisted of six different roads, over each of which the passenger was obliged to purchase his tickets separately. There was then no system of checking or registering baggage, and it was transported wholly at the passenger's risk. The westbound passenger left Buffalo on a steamboat, or packet, and travelled to Toledo or Detroit, from which points ran stage-coaches, landing ultimately at the then frontier point of Chicago. West of Chicago there were no public means of locomotion, except a few local stage-coach lines reaching

out to the new towns on the prairies and in the forests beyond.

Even at that early period, when America was beginning to boast of its unexampled transportation facilities, it required about ten days to make the journey from the Atlantic coast to Chicago, and there were three different means of transportation, the last of which was characterised by a degree of discomfort and of personal hazard scarcelyto be imagined to-day. The limited trains of the trunk lines now cover the distance in twenty-four hours, and the traveller has scarcely a want or a desire, natural or artificial, unfulfilled. He sleeps, eats, reads, writes, smokes, amuses himself, transacts business, bathes, and is shaved with the utmost comfort and safety while speeding over the country at the rate of fifty miles or more per hour. So complete and so perfect are all the modern devices to insure the safety and comfort of the traveller upon the great American lines that nothing more would seem to be left to be invented, devised, or applied to add to it or to reach ultimate perfection.

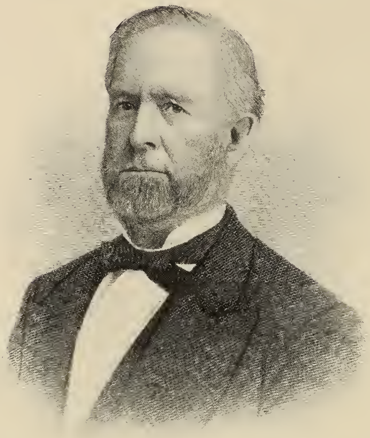
The first sleeping car was devised by Theodore T. Woodruff, who constructed a small working model in 1854, at Watertown, N. Y., and whose first patents for "Improvement in Railroad Car Seats and Couches" were issued on December 2, 1856. Mr. Woodruff was then a resident of Alton, Ill., and attached to the St. Louis, Alton and Terre Haute Railway. The invention was original and wholly unprecedented, but, at first, met with no favour from the railroads, and for several years Mr. Woodruff was obliged to defend his patent in the courts before his priority of invention was fully established.

Having built his first sleeping car, he was at length, after much persuasion, permitted to attach it to the night express on the New York Central Railroad between Albany and Buffalo, making its first trip on October 26, 1856. He personally managed the car, charging each passenger fifty cents for its use, and was delighted when a dozen passengers took lodging with him for the trip. Gradually the car became talked about among travellers, and the demand for it was effectively and permanently established. So little was the sleeping car appreciated by the railroads when first introduced that the New York Central actually charged Woodruff full fare while he was conducting his car and trying to introduce its merits to the travelling public; but President Erastus Corning, of the railroad company, finally issued a free pass to Mr. Woodruff, and thenceforth he ran the car without having the gross

A PRIVATE PULLMAN CAR INTERIOR

earnings nearly exhausted by his own fare for the trip.

Having established the sleeping car on the New York Central, and on the Lake Shore and Michigan Cen-



THEODORE T. WOODRUFF, THE INVENTOR OF THE SLEEPING CAR

tral Railroads, Mr. Woodruff took his car to Pittsburgh, where it attracted the attention of Mr. Edgar Thompson, then president, and Mr. Thomas A. Scott, general superintendent, of the Pennsylvania Railroad, as well as Mr. Andrew Carnegie, then a young man in Mr. Scott's office. These gentlemen became interested in the invention, the Central Transportation Company was formed, and the manufacture of cars begun.

In the meantime, the same idea began to find development further West in the United States. Mr. George M. Pullman, after a trip in one of Mr. Woodruff's cars from Buffalo to Chicago, conceived the notion that they might be greatly improved, and that passengers might have upon sleeping cars comforts equal to those then provided upon steamboats. In 1859 he altered some day coaches on the Chicago and Alton Railroad, converting them into sleeping cars, which were considered a material advance upon any previously constructed.

In 1864 Mr. Pullman constructed a new car in the Chicago and Alton Company's yards at a cost of $18,000 (about £3600), which was a direct departure from the previous plan. It was named *The Pioneer*, and designated by the letter "*A*," as it was then supposed that the letters of the alphabet would be quite sufficient for all the sleeping cars that might ever be constructed. It had improved trucks and a raised deck, and was two feet and a half higher, and a foot wider, than any car then in service, necessitating considerable alterations in station platforms and bridges along the line.

The first cars of Mr. Woodruff were scarcely more than old-style, flat-top day coaches, provided with mattresses and blankets, stored at one end during the daytime, and spread upon the seats, which were so constructed as to form a bed. Each car accommodated about sixty passengers. In the Pullman car there was a double-berth below and two single berths above, let down by hangers or fixtures on the side of the car. The charge was $1 for a lower, and fifty cents for an upper berth.

Prior to Mr. Pullman's experiment, however, the first regular sleeping car,

WEBSTER WAGNER

constructed according to modern ideas of what a sleeping car should be, was built by a practical mechanic named Thompson, at the car works of the Wasson Manufacturing Company, at

A LADIES' COMPARTMENT IN A DRAWING ROOM CAR

Springfield, Mass., in the fall of 1857, or early in 1858, and was bought from him by the late Webster Wagner. Mr. Wagner was a native of Palatine, N. Y., of German descent, and was apprenticed to the wagon-maker's trade, but afterwards became connected with the New York Central Railroad, and there applied his mechanical knowledge to the invention of a more luxurious waggon than had then been dreamed of. He subsequently became wealthy, and was serving his fifth term in the State Senate of New York when he was killed in one of his own cars in a railroad accident. It is a singular fact that Mr. Woodruff also was killed by a railroad accident ten years later.

One of Wagner's first improvements in sleeping cars was to make them wider and higher, and then came improvements in ventilation, as it was found that passengers occupying the upper berths suffered from the confined and vitiated atmosphere. This resulted in the introduction of the distinctive feature of the raised roof or double deck, afterward applied also to the ordinary American passenger coaches. Another improvement was the introduction of the adjustable upper berth which permitted of the storing of the bedding in the daytime in the space behind it. Four of these improved sleeping cars were built by Wagner and placed in regular service on the New York Central in 1858, running between New York and Niagara Falls. He subsequently turned his attention to drawing room cars for day travel, and in 1867 introduced the first car of this description.

It was not until 1861 that linen was used in the cars, the only bedding previously employed being woollen blankets and ordinary mattresses; but about that

A READING ROOM IN A WAGNER DRAWING ROOM CAR

time were introduced a pillow, a hair mattress, linen sheets and coloured woollen blankets. It was in the fall of 1861 that Mrs. Abraham Lincoln and four other ladies made the trip between Albany and New York. They were the first women passengers who had ever travelled in a sleeping car, and it was their courageous example that soon induced other women to use this improved and more comfortable form of conveyance.

It is curious sometimes to note the impressions of the first use of this wonderful improvement in transportation. Madame Grandin, travelling to the World's Fair at Chicago in 1893, records her experience after leaving Niagara Falls in an amusing way:—

"It is for me an atrocious torture, the nights passed in these sleeping cars. Men and women have their beds one against the other, a single curtain protecting them against indiscreet glances.

"Entirely worn out, I threw myself on my bed; my husband, placing himself in front of me, did the same, and, greatly fatigued, I at last fell asleep, soothed by the respiration, more or less sonorous, of our companions of the sleeping car."

On the other hand, that experienced traveller and critical observer, Anthony Trollope, making the same journey from Niagara Falls to Chicago more than thirty years before, wrote with greater appreciation:—

"In making this journey at night, we introduced ourselves to the thoroughly American institution of sleeping cars,—that is, of cars in which beds are made up for travel. The traveller may have a whole bed, or half a bed, or no bed at all, as he pleases, paying a dol-

lar, or half-dollar, extra, as he chooses the partial or full fruition of a couch.

"I confess, I have always taken a delight in seeing these beds made up, and consider that the operations of the change are generally as well executed as the manœuvres of any pantomime at Drury Lane. The work is usually done by negroes or coloured men; and the domestic negro of America is always light-handed and adroit.

"The nature of an American car is no doubt known to all men. It looks as far removed from all bedroom accommodations as the baker's barrow does from the steam engine into which it is to be converted by Harlequin's wand, but the negro goes to work very much more quietly than Harlequin, and for every four seats in the railway car, he builds up four beds almost as quickly as the hero of the pantomime goes through his performance.

"The great glory of the Americans is in their wondrous contrivances, — in their patent remedies for the usually troublous operations of life. Everything is done by a new and patent contrivance; and of all their wondrous contrivances, that of their railroad beds is by no means the least. For every four seats the negro builds up four beds,—that is, four half beds, or accommodations for four persons. Two are supposed to be below, on the level of the ordinary four seats, and two up above, on shelves which are let down from the roof. Mattresses slip out from one nook, and pillows from another, blankets are added, and the bed is ready.

"Any particular individual, an Islander, for instance, who hugs his chain, generally prefers to pay the dollar for the double accommodation. Looking at the bed in the light of a bed,—taking, as it were, an abstract view of it,—or comparing it with some other bed or beds with which we occasionally have acquaintance, I cannot say that it is in all respects perfect; but distances are long in America, and he who declines to travel by night will lose very much time. He who does so travel, will find the railway beds a great relief."

Another traveller of distinction, who came to the World's Fair about the same time as Madame Grandin, but whose widely different views on the subject of American railway transportation were justified by his extensive experience, was the famous *littérateur*,

CAR VESTIBULES

Octave Uzanne. He wrote enthusiastically, as follows:—

"A comparison between the railroads of the two countries does not appear to us out of place, but it is afflicting to our national pride. In the United States the 'way' is much broader than

A DINING ROOM IN A PRIVATE CAR

ours, and the sleepers are closer together; as a result the carriages are more spacious, travel with greater stability, and are less subject to derailment. There is less shaking and jolting of the passenger, and he is not deafened by the noise of the wheels on their axles.

"The American cars, two or three times as long as ours, are fixed at each extremity upon four-wheeled trucks; this disposition diminishes the noise. One enters the cars by steps and a platform, which are found at the rear of the train, and vestibules connecting them. Each seat for two persons is placed close to a window on the right and on the left, leaving in the centre a passage broad enough to permit going through from one end to the other of the train, to descend or to walk about, or to go to the very complete toilet-rooms, which, besides their tanks of ice water, are usually provided with lavatories of hot and cold water, permitting very refreshing ablutions, and dispensing with the necessity of leaving the train for many days without inconvenience when the journey must extend over two-thirds of a week.

"The trains have their kitchens and dining rooms, and, thanks to a Belgian company, we have adopted this innovation on some lines of our systems. The immense American cars are transformed each night into sleeping cars, provided with large double beds. A bed of this kind, provided with sheets and blankets, costs twelve and a half francs for a night in these luxurious carriages called Pullman or Wagner cars. A porter and an interpreter accompany all the trains, and you find on board all the service and all the commodities that a first-class hotel can furnish. Besides, there is always a passenger car and not a baggage car at the rear of the train. This car forms a place of observation in which are placed seats permitting one to enjoy the scenery. Smoking is permitted only in the smoking-rooms, which are furnished with comfortable sofas.

"The checking of baggage is done in the most simple and speedy fashion, —not the least writing, no placards pasted on; they attach to your trunk a numbered disc of copper and give you

A COSY CORNER

another with a corresponding number, by means of which you claim it on arrival. Besides, they give you the freedom of about sixty kilograms of baggage, if not more.

"In America you can go from New York to San Francisco more easily, 'cane in hand,' than from Paris to Bois Colombes; divers companies, called express companies, relieve you of the care of looking after your baggage, great or small, and you are sure of always finding your trunk at the hotel soon after, if not before, your arrival.

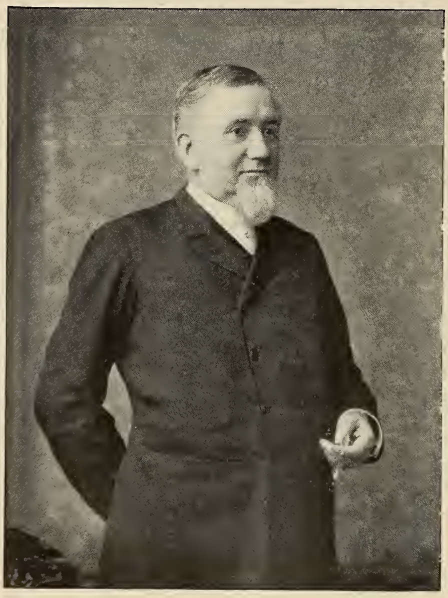
"What shall I say of this locomotion? I do not know if the condition of the rails is as perfect as in England, if the danger of accidents is not much greater than in France; but so far as comfort is concerned, of the absolute consideration of the human freight and the welfare of the individual, there is nothing to discuss; one finds in America the *ne plus ultra* of the kind.

"It is an unknown and unexpected pleasure to the European to feel himself carried softly and easily, almost noiselessly, through an unknown country, and see himself served on a sign or motion, fed, barbered, washed, brushed, and living in a veritable rolling home, surrounded by beautifully worked woods, hangings, and decorations, free and unfettered, with the right of going

A BARBER SHOP ON A MODERN DRAWING ROOM CAR

and coming, or walking from one end to the other of this mansion flying through the air, without feeling the oppressive weight of the wooden cloisters which make of our compartments disguised prisons, to which one submits with resignation during his time of incarceration."

If Madame Grandin had ever taken the " wagon-lit " from Paris to Nice, or even upon the Oriental Express, she would have readily recognised the vast superiority of the American sleeping car. In truth, the Hon. William E. Curtis, writing from Berlin last year, and referring to the comparatively exorbitant charges upon the high-class trains and sleeping cars of the European Continent, averaging fully threefold the similar charge in America, adds with force that "no expenditure of money will procure to the traveller anything like the comforts and conveniences that he finds upon the trains of any first-class railroad out of the city of Chicago."



GEORGE M. PULLMAN

It is quite the fashion among Americans to commend the British for superior solidity and strength in all constructive work, including car-building, but the truth is that an ordinary Wagner or Pullman car of to-day possesses a strength, if it has not the weight, rarely, if at all, attained by any British or Continental cars; while in elegance and richness of furnishings and decoration and the assemblage of those thousand and one little contrivances to which Trollope has referred, and which add so immensely to the comfort of the traveller, the American sleeping or parlour car is beyond all comparison.

Probably the finest and most comfortable of the European sleeping and saloon cars are those operated between London and Liverpool, and between London, Glasgow and Edinburgh, and, on the Continent, those on the Oriental Express, between Paris and Constantinople. The system of the Compagnie Générale des Wagons-Lits embraces practically all the long-distance lines of Europe, and includes quite a variety of combinations of sleeping cars with berths, adjustable couches, reclining chairs, parlour and restaurant cars; but, with few exceptions, they appear crude to the American traveller, and are singularly deficient in the most ordinary conveniences that he has learned to consider so necessary as to take them as a matter of course on the American lines. The greater degree of comfort and convenience are, in Europe, found almost exclusively in the private cars and trains of sovereigns.

Queen Victoria was the first monarch to enjoy the luxury of a private train. Her example was followed by the Czar of Russia, whose magnificent train of eleven cars was completed in 1894 at Alexandrovsky. This train, which is entirely Russian in its construction, with the exception of the apparatus for lighting and heating, was, from precautionary motives, duplicated by another train of precisely the same exterior appearance, which sometimes precedes and sometimes follows that containing His Imperial Majesty, so that it is impossible for any but the officials interested to tell which is the real imperial train. In addition to abundant accommodations for their Majesties and suites, it provides for a train crew of twenty-

A BUFFET SMOKING CAR INTERIOR

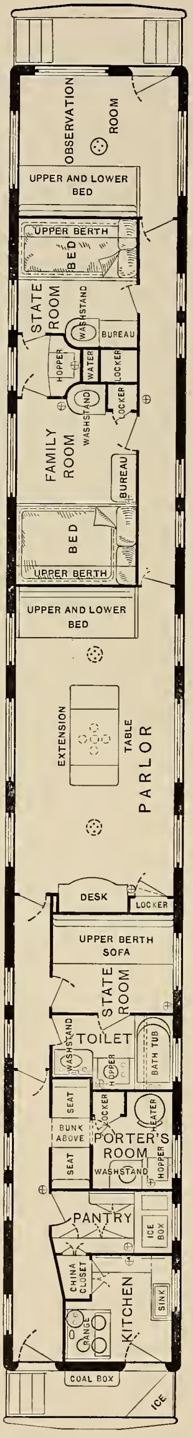
six, including expert mechanicians, and carries also such a supply of duplicate parts and utensils and various appliances as to enable the train to proceed upon any railroad system in Europe.

Just before the Czar's visit to Paris two years ago, the Société de Construction de St. Denis completed for President Faure a presidential train of seven cars, the first use of which was expected to be the transportation of the Russian visitor from Cherbourg to Paris. The French journals spoke of the decorations of these trains as mediocre, but at least in the matter of hangings, textile fabrics, and decorations, both were probably superior to anything in Europe.

In America, however, many of the private cars constructed by both the Wagner and Pullman companies far surpass them. The Pullman Company last year completed a train for President Diaz, of Mexico, the luxury and elegance of which must be seen to be duly appreciated, and the same is true, not only of the Wagner private cars, but of several other trains devoted to the use of His Majesty, the American Citizen. It is worthy of note, too, that one of the first private cars constructed in America was built by the Wagner Company at Springfield, Mass., for the Khedive of Egypt, and a picture of it for many years adorned the stock certificates of that company.

One of the latest and finest of these magnificent trains that have come from the Wagner shops is composed of seven cars, the description of which reminds one of some gorgeous Oriental palace in the Arabian Nights.

The private cars combine all the latest improvements for the comfort of the passenger, and are equipped with the most approved appliances for insuring safety. These cars have been specially designed and constructed for the pur-



A PLAN OF THE PRIVATE CAR "ELLSMERE"

pose of supplying to parties on extended trips the conveniences and comforts of a first-class hotel. They have large saloons, furnished with luxurious movable chairs and couches, extension centre tables, writing desks, reading lamps, and every requisite to make a long trip as comfortable and enjoyable as possible.

The state-rooms have large and comfortable beds, stationary washstands and closets and drawers for clothing. The kitchens have every facility for furnishing meals to passengers to the number of the capacity of each car, and are fully equipped with kitchen utensils, china, silver, tableware, table linen, etc. The observation room in each of these cars, at the opposite end from the kitchen, is arranged to command the largest possible view, the large plate glass windows affording advantages in this respect that cannot be obtained in ordinary cars of this class.

A good example of these private cars is available in that shown on this page. This car, known as the *Ellsmere*, is 79 feet in length, 10 feet in extreme width, and a little over 14 feet in extreme height from track. It will accommodate from ten to fourteen persons. There are two state-rooms, finished in mahogany, with two double berths in each room, and connecting toilet rooms with hot and cold water, bureaus and other conveniences. The third, or family room, is 11½ feet long by 7 feet wide, with a stationary bed 5 feet wide, having drawers below and a single or upper berth at the side for children. Connecting with this room is a toilet room, containing a washstand with hot and cold water, a large locker, mirrors, and other accessories.

The observation room, shown in the annexed plan, is finished in quartered English oak, and has a sofa section and luxurious armchairs. The parlour or dining-room is 18 feet long, and has an extension table that will seat twelve persons comfortably. At one end of this room there is a large mahogany writing desk, with bookshelves over it, and a sofa section at the opposite end. The berths in this section and in the section in the observation room have all the privacy of a state-room when, separated from the adjoining parts of the car by curtains, they are occupied at night.

There is a toilet room for the general use of the occupants of the car, and a bathroom connecting. There is also a porter's room for storing baggage, and a double berth for porters or attendants. The different woods used in the construction have been most carefully selected and elaborately designed and carved. The pantry, china closet and kitchen are finished in black walnut, and the linen and tableware were specially imported for this particular car. The carpets, portières, draperies and upholstery were selected to correspond with the woodwork and decorations, and the general arrangements and finishing combine to make it one of the handsomest as well as most convenient private cars ever built.

The author of "California and Alaska" a few years ago conceived, and for the first time executed, the idea of organising a complete private

A DINING CAR INTERIOR

train for his family and friends upon a proposed tour. It included a baggage car, a dining car, and two special cars. The first car was a so-called combination car. The forward part was used for the storage of baggage; next to this compartment was a sleeping room for the cooks and porters; after this came a bathroom, and next adjoining a large smoking or drawing-room, at one end of which was a piano and at the other a desk, a complete library, the proper compartments for guns, fishing rods, and smoking paraphernalia. This smoking-room was intended as a sitting-room for the men of the party during the evening or daytime.

The dining-room came next. All the tables had been taken from it, and in their place an ordinary dining table, side tables, etc., had been put in, the same as in a house. Next came a car which had been remodelled into a nurs-

PRIVATE CAR DRESSING ROOMS AND LAVATORY

ery, and which was occupied by the ladies, children, nurses and maids of the party. Last of all was the private car *Ellsmere*, just described. The train was also so arranged as to be heated by steam from the engine.

The train was furnished by the Wagner Palace Car Company, and was run what railroad men call " special " from start to finish,—that is, it was entirely independent of time-tables, starting when desired, and running at any rate of speed desired. It made a total mileage of 11,192 miles, covering twenty-five States and Territories, and returned to the starting point, New York, without any accident or detention. Surely the luxury of travel could not well reach a higher degree of perfection.

The dining car is scarcely less important as an element of comfort and luxury in travel than the sleeping car, for man must eat, whether he sleeps well or ill or not at all, and many experienced travellers have expressed the opinion that in the enjoyment of a well-cooked and well-served meal on a well-appointed train, speeding rapidly through agreeable scenery, over smooth and well-constructed roads, the acme of this luxury is to be found.

As in the case of the sleeping cars, the dining or restaurant cars are decided innovations upon European railways, and in the character of their service do not well bear comparison with those operated upon the principal American lines. The first hotel car was named *President*, and was placed in service on the Great Western Railroad, in Canada, in 1867. It was practically a sleeping car with a kitchen and pantry in one end, and movable tables upon which meals could be served, placed between the seats of each section.

This was followed by the first dining car, called *Delmonico*, and operated on the Chicago and Alton Railroad in 1868. This was a complete restaurant, having a large kitchen and pantries in one end, while the main body of the car was fitted up as a dining room in which passengers could eat comfortably and leisurely.

The dining car business, when operated by the railroad company itself, is in charge of a special superintendent, and in the case of the Wagner and Pullman companies, is in charge of commissary departments, located at convenient points along the line, from which supplies are obtained as needed. In spite of the difficulties and disadvantages that necessarily attend a service of this kind, it has reached such a degree of perfection that passengers upon a first-class line expect to receive similar service to that of a first-class restaurant in a city. Nothing can exceed the infinite painstaking care with which every department of the service is looked after, and no expense is spared to secure the best viands that the markets afford, and to cook and serve them in excellent manner. The expense incurred is great. It is, in fact, rarely equalled by the receipts, and the first cost of a meal upon one of the great limited trains sometimes exceeds the price paid by the passenger when served to him with all the appetising array of sparkling cut-glass, glittering silver, dainty china and irreproachable napery. No people are such constant and universal readers as the Americans, and it is not surprising that their literary tastes should find a place in the luxury of American railway travel, and on the fast trains of the principal lines are found "buffet-library" cars, containing well-selected standard books, as well as reference volumes, city directories, and the current periodicals. Passengers can select from the printed catalogue the book desired, which will be brought to them by the porter.

Such comparatively recent improvement as the patent buffer at the end of each platform, the broadening of the platforms to the width of the cars, and the system of platform vestibules, add much to the comfort and safety of the passenger. By means of the buffer now in use, the platforms of two cars are apparently merged into one, give a steady motion to the train, and tend also to prevent telescoping.

The lighting of the cars, too, by Pintsch gas, stored in cylindrical tanks beneath the cars, is a great improvement, as it produces, with entire safety,

a softly radiant light, nearly or quite as brilliant as the electric, and less dazzling, and more agreeable to the eye. The deadly car stove no longer finds a place in the palace cars, but heat is supplied by hot water, and more recently by electrical appliances.

These are but a few of the numerous contrivances for allaying the usually troublous operations of life of which Trollope has written, that have come into use since that genial British traveller has passed away. In this day, no more than in the days of long ago, can we look into the future and see what wonderful improvements and inventions may yet be made, but certainly in the present marvellously advanced condition of science and of mechanical arts, it does not now seem possible, whatever the future may bring forth, to add much to the degree of comfort and of luxury that the traveller obtains upon the world's best equipped railroad trains.

THE TRANSPORTATION AND LIFTING OF HEAVY BODIES BY THE ANCIENTS

A Probable Method

By J. Elfreth Watkins, C. E., Curator of Technology, U. S. National Museum, Washington

THE ability displayed by the ancients in transporting heavy objects from place to place, and in raising them many feet above the surface of the ground in the construction of temples, palaces, and pyramids, has long been a source of wonder. It may, indeed, be truly said that the engineers of the present era would find it difficult to perform similar feats, even when aided by the most improved appliances devised through the ingenuity developed in this inventive age.

So impressed with amazement at the achievements of the ancient architects have trained archæologists become that not infrequently the opinion is expressed that these men, whose work has withstood the ravages of scores of centuries, must have been aided by well-devised machines, possibly operated by one or more of the generated forces.

Notwithstanding these conjectures, in the many careful and thorough explorations made in late years the remains of no hoisting machine have thus far been discovered, nor has there been found, either in the Assyro-Babylonian cuniform inscriptions or in the Egyptian hieroglyphics, an account or description of the processes employed by the ancients in lifting heavy masses to extraordinary heights. In fact, no equivalents for the words "derrick," "pulley," "winch," etc., have yet been identified in these ancient records to encourage the belief in a *seaculo sapienti.*

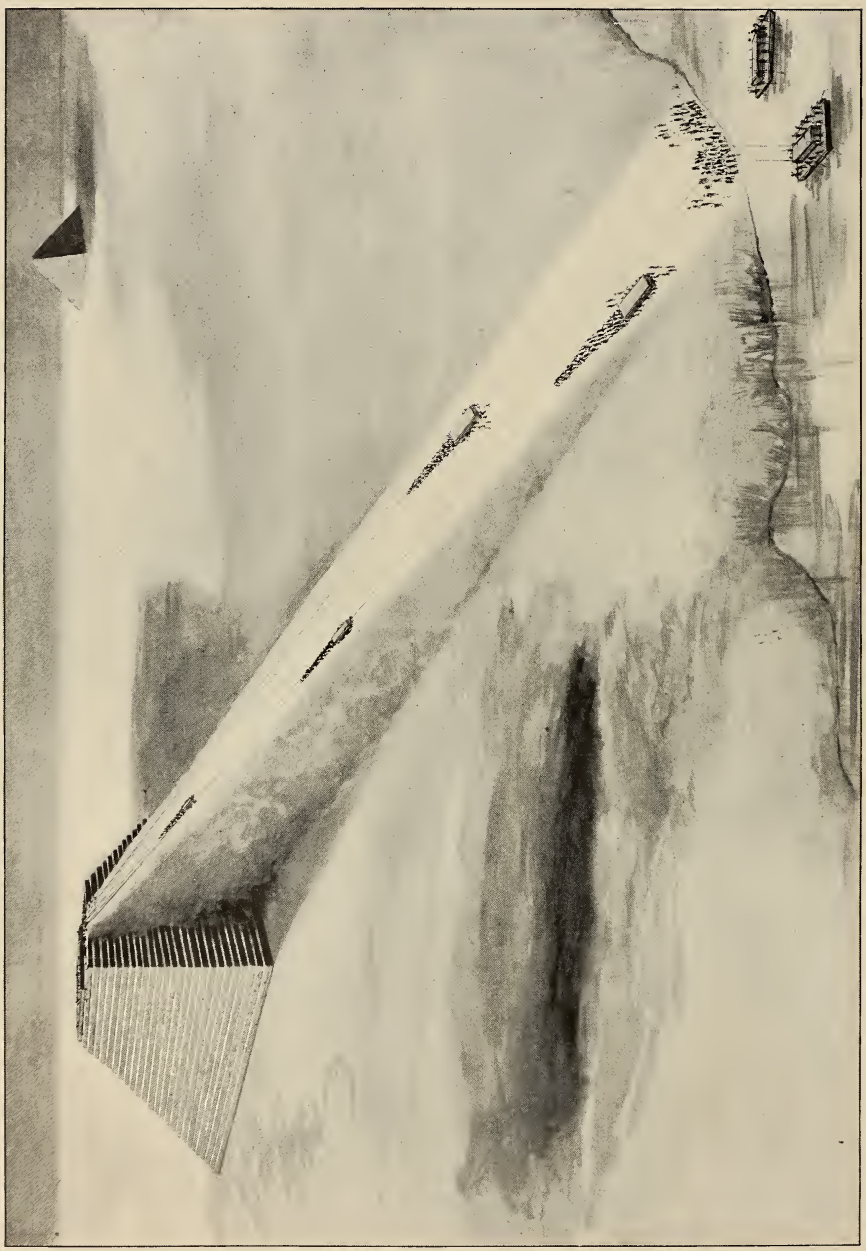
It is the purpose of this paper to explain how many of the edifices now regarded as remarkable could have been constructed by primitive tools and simple methods. Eight years ago, while the writer was making the investigations which led to the publication of a paper, entitled "The Beginnings of Engineering," presented before the American Society of Civil Engineers, access was had to many drawings and photographs of ancient mural paintings and carvings in relief in the collections of the United States National Museum and in the great libraries of Washington and New York city.

FIG. I

While several pictorial remains are in existence, showing how, by the aid of

BUILDING A CROMLECH IN PREHISTORIC TIMES ON THE SIDE OF A NATURAL HILL

Reproduced from a manuscript on "Prehistoric Architecture," by Dr. Thomas Wilson



A POSSIBLE METHOD OF INCLINED PLANES BY WHICH THE PYRAMIDS MAY HAVE BEEN BUILT

sledges, rollers, and levers, huge images of stone were moved over ground from the quarry to the building under construction, nothing has been found to show how these heavy masses were lifted into position. In examining the photographs referred to, it was noted, especially in the pictorial representations of Assyrian and Egyptian remains, that many figures are represented in various attitudes carrying something in baskets or bags. It occurred to the writer that this "something" was clay or other kind of earth, and a method of lifting heavy bodies into position suggested itself, in which the sledge, the roller, the lever and the inclined plane, made of earth, were the only mechanical powers necessary to be utilised, no pulleys, cranes or other machinery being employed.

From the earliest times the erection of embankments of earth has been carried on by savage nations and primitive peoples. The earthworks left by the mound builders in America and Europe are conspicuous evidence that the digging and carrying of earth was practiced on a large scale in many localities, long distant from one another, centuries ago.

Let us see how, by the aid of inclined planes of earth, the huge stones used in the construction of dolmens or cromlechs could be put in position by the

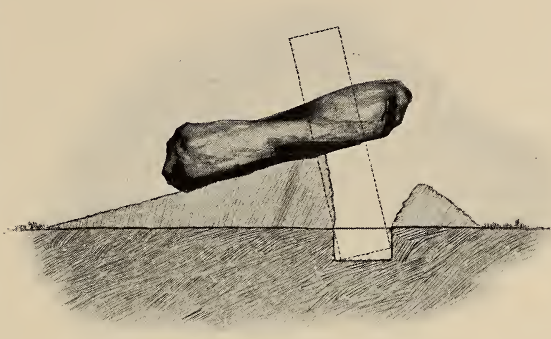


FIG. 2

use of primitive appliances! The stone posts could be moved to the desired place and erected in a vertical position in the manner indicated by the several accompanying drawings. Fig. 1 shows the stone post lying flat and supported upon rollers. Fig. 2 shows two piles of

FIG. 3

earth, dug from the pit in which one of the posts is to stand. The stone slab can be rolled up the inclined plane and tilted into position, and, by the use of levers and pry bars, be made to stand upright; and when the second post was erected

by a similar operation, and the space between the posts and around them filled with earth, the top stone or lintel could be placed in position after being elevated to the desired height on another inclined plane, made of earth, as shown in Fig. 5. These operations being completed, the earth could be returned to the pits from which it was dug (see Fig. 6), and the surface of the ground levelled.

Since these lines were written, the author has received the following communication from Dr. William H. Dall, of the United States Geological Survey:—

"During a visit to the Island of Jersey (Channel Islands) in 1878, while wandering over the hills, I noticed, among many dolmens scattered about, one which seemed to have never been finished. The sides stood erect, and

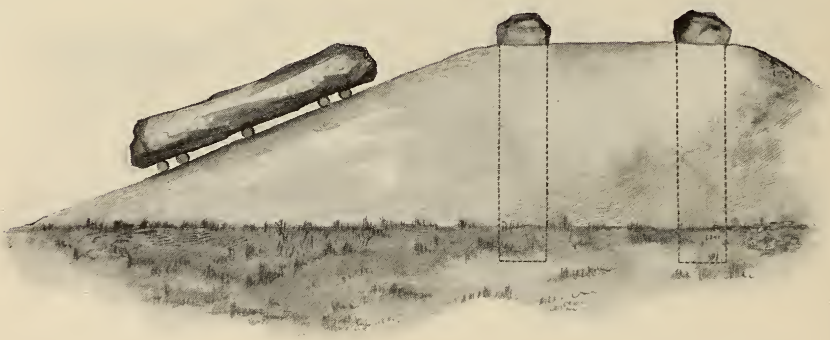


FIG. 5

one enormous roofing slab had been laid in place, covering about half the cavity at the inner end. Behind it and against the erect slab, forming the end of the chamber, was an inclined plane of earth, beaten very hard, and extending from the level of the uprights to the general level of the soil. Here was a clue to a very simple explanation of what had often puzzled me; how the prehistoric people without tools could have raised such heavy weights as the roofing slabs of the dolmens to the positions in which we find them. It was evident that cords and rollers, with a sufficient number of sturdy savages, would have been amply sufficient for the purpose in the case

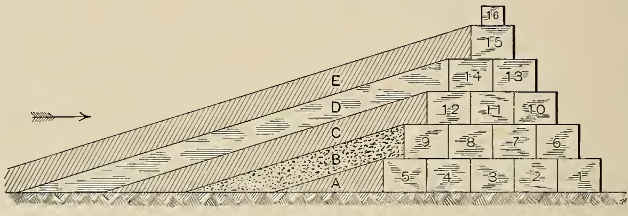


FIG. 4

before me. The thorough manner in which the clay of the inclined plane had been consolidated was evident when it was considered that the denudation of it by the elements during unknown centuries had been insufficient to noticeably reduce its level or conceal its evident purpose."

The erection of a cromlech on the side of a natural hill is shown on page 109, has been reproduced from manuscript on "Prehistoric Architecture" by kind permission of Dr. Thos. Wilson.

The construction of the Egyptian pyramids, for centuries a matter of wonder, could have been performed by similar methods. Let us suppose that each of the stone blocks used had a rectangular base, being half as thick as wide, and that they were moved from the

quarry to the pyramid in the direction indicated by the arrow in Fig. 4, block No. 1 being first placed on rollers and moved into position! The stone blocks numbered 2, 3, 4, and 5 could then have been transported along the surface of the ground in the same manner, and so could the other stones in the same tier, which are not shown in this view. An embankment at a 20 per cent. or 30 per cent. grade (see section *A*) could then have been constructed by carrying earth from pits beyond the continuation of the boundary lines of the base of the pyramid. Over the surface of this plane, extended towards the quarry, the second tier of stones, of which blocks numbered 6, 7, 8 and 9 are visible, could then have been put in place; embankment *B* could then have been constructed, blocks numbered 10, 11, 12 and those behind them being put in place; and so on, by the aid of the additions to the embankments, *C*, *D* and *E*, the remaining stones could have been put in position.

When the pyramid was complete, the earth could have been removed from in front of it, the pits filled up, restoring the original condition of the surface of the ground, leaving no hint to gratify the explorer, forty centuries after the work was done.

Let us see what labour this method would have involved in the construction of the pyramid of Gizeh, the largest of its kind, which is approximately 150 yards high and 250 yards square at the base! As is well known, in building this pyramid, which is located three miles south of Cairo, two kinds of stone were used, limestone and red granite. The limestone was quarried at El Massarah, forty-five or fifty miles from Gizeh, while the red granite was brought from Assouan, near the first Cataract, over five hundred miles. Both of these quarries were located on the River Nile.

In the foreground of the illustration on page 110 are to be seen rafts laden with stone blocks, brought from the quarries. Upon the sloping embankment blocks are being drawn on sledges, perhaps equipped with rollers, to the highest point to which the structure has been built, the inclined plane being gradually made longer and higher with earth brought from the pits on the right and left. The highest embankment necessary when the workmen reached the top course, assuming that a 20 per cent. grade was adopted, would have been 750 yards long, containing about seven

FIG. 6

and one-half million cubic yards, if the sides of the earth embankment would stand at an angle of 30 degrees, which is not at all improbable.

Assuming that one labourer could have placed two and one-half yards (about 20 barrow loads) of earth on an average each day on this embankment, 10,000 men could have built it in twelve months of twenty-five working days. It is stated that one hundred thousand men were employed for twenty years in the whole work, so that, according to this calculation, the construction of this embankment would have occupied only a small portion of the total time consumed.

The false work to support the walls of the interior chambers of the pyramids could also have been made of earth rather than of timber. It should be remembered that heavy lumber for scaffolding must have been brought over long distances, and that the framing and erection of any structure of sufficient strength to bear heavy weights would have required more skill and knowledge than the building of the pyramid itself by the method above described.

In the great temple of Rameses II. is to be found a colossal statue of that king, which equals in dimensions and exceeds in weight any other Egyptian monolith, being 60 feet high and weighing 887 tons, 5½ hundredweight. It was made from a single block of red granite brought from the quarries at Assouan, 135 miles distant, by the River Nile.

At Baalbec, Syria, are to be found the ruins of three temples, one of which has been given the name of Trilithon, "Three-stone-temple," from the extraordinary proportions of three of the stone blocks found in it, each being over 63 feet in length, 13 feet in height, and proportionately thick. These stones now rest in a wall over 20 feet above the present surface of the ground.

In the solution of the problem of putting similar huge blocks in place at the present day, the utilisation of inclined planes of earth in the manner just described might well be considered by the modern engineer before adopting a more complex method. In fact, since the various details of this method of construction have suggested themselves, the writer has examined photographs of many ancient structures and has yet to find one that could not have been constructed to a great extent according to the practices just described. Until the principles of the true arch were understood it was less difficult to move and erect long blocks of stone by these primitive methods than to place smaller units over the openings of structures designed in accordance with the types of ancient architecture, in which the arch, with a keystone, was lacking.

Especially was this true in an era when the value of time was not considered, and slaves were to be obtained by thousands, at small cost, to toil and sweat to gratify the ambition and perpetuate the fame of kings.

Happily for our race and time, the crack of the Egyptian slave master's whip and the weird cries in cadence of the batallions of swarthy labourers, while tugging in unison to draw or hoist the monolith, has given place to the puffing engine and the rumble of revolving wheels; but, mayhap, in the years to come, the engineering methods in vogue at the end of this eventful century will seem almost as crude to those who will practice in the new fields of applied science on the borders of which we seem to stand as these primitive methods of the ancients now appear to us. Whether the anticipations for the future shall be realised or not, and proud as we may be of the advances made by discovery and invention in our age, we must not forget that the patient perseverance of the engineers of antiquity, who, by brawn and muscle, and unaided by mechanism, built wiser than they knew, have been rewarded by the preservation of an indelible record of their achievements in the material remains of their edifices that have withstood the ravages of centuries. Will fate so favour the engineer of the nineteenth century, versed in the laws of modern science, and skilled in the practice of the mechanic arts?

HIGH EXPLOSIVES IN NAVAL WARFARE

Their Composition, Uses, and Present Value

By Dr. Charles E. Munroe

ALTHOUGH the substances that have been proposed for use as explosives number many hundred, yet most of them possess no practical value, and owing to the conditions which they must satisfy, only very few can ever be used in warfare, except as emergency explosives. The explosives which are employed belong to one of four classes,—gunpowders, organic nitrates, nitro substitution compounds, and fulminates.

Gunpowder consists of potassium nitrate, charcoal and sulphur, intimately mixed by grinding the powdered materials, when moistened with water, under heavy stone or iron wheels and pressing the material thus obtained into the desired form of grain. The gunpowder which has for a long time been in use, and which during the late Spanish-American war was issued for use with the American Springfield rifle, consists of seventy-five parts of potassium nitrate, fifteen parts of black charcoal, and ten parts of sulphur, which, after mixing on the wheel mill, is pressed into cakes. These cakes are then broken into coarse particles in a breaking-down machine, and the angular, irregular grains are sorted out by passing the broken mass over graduated sieves.

The more modern gunpowder, known as cocoa or brown prismatic powder, contains under-burned or brown charcoal, so that some of the carbohydrates remain, and the proportions of the ingredients are also different, the German cocoa being compounded of 78 parts of potassium nitrate, 20 parts of charcoal, and 3 parts of sulphur. The mixture is compressed in a powerful hydraulic press into separate grains, which have the form of an hexagonal prism, and which are perforated through their longer axis by a hole or canal.

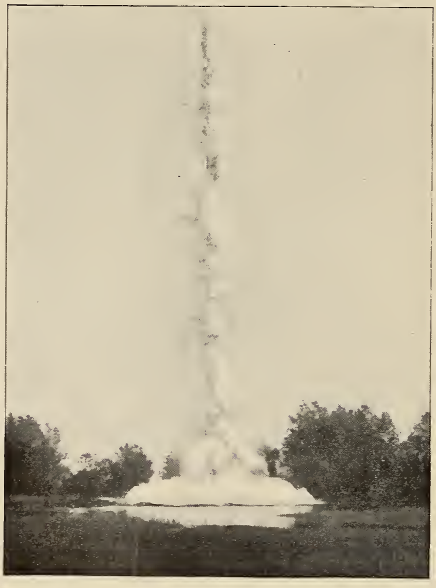
The brown prismatic grains for the United States Navy guns measure 1.26 inch in diameter, 1.05 inch in height, with a hole 0.32 inch in diameter for large grains, and 0.94 inch diameter, 0.87 inch in height, and 0.17 inch diameter of canal for the smaller grains. The advantage which this brown gunpowder possesses over the black is that as it is slower burning it is less *brisante*, and that, therefore, a higher velocity may be imparted to the projectile without bringing an undue pressure upon the walls of the gun.

It is, however, not only slow-burning, but also difficult of ignition, and it is, therefore, necessary to press grains of similar form and dimensions from the quicker burning and more easily ignited black powder, and to place a number of these ignition grains in the base of the cartridge which is to be placed in contact with the primer in the breech block of the gun.

An absurd situation grew out of this necessary adjustment at an official exhibition given at Fort Washington, on the Potomac, a few months ago. A deputation from the United States Congress was invited to witness the behaviour of a disappearing gun that had recently been mounted at that important point of defence. The first round was

fired, to the amazement of some and the satisfaction of all. On the second round the magnificent weapon was elevated and the order to fire given, but without effect, and after investigation it was ascertained that the failure was due to the cartridge bag having been reversed in loading the piece.

The properties of gunpowder are so well known that it is unnecessary to dwell upon them. Although there is some question as to the permanency of brown prismatic powder, yet on the whole, its reliability constitutes its chief advantage. A marked disadvantage, and one which recent events have strongly impressed upon the public, is



EXPLOSION OF A SUBMARINE MINE CHARGED WITH JOVEITE

the smoke which it produces when fired, more than fifty per cent. of the total weight of the powder charge being thrown out as solid matter to foul the atmosphere, becloud the gunner, and make his situation a conspicuous target for the enemy.

Many smokeless powders are now known and used, and all of the principal ones belong to the second class of explosives mentioned above, as they are composed wholly, or in part, of organic nitrates. The most typical members of this class of explosives are gun-cotton, which was discovered by Schönbein in 1845, and nitro-glycerine, which was discovered by Sobrero in 1847. Gun-cotton is made by immersing cold, thoroughly dried and thoroughly cleansed cotton fibre in a mixture of nitric and sulphuric acids, when nitrogen oxides from the nitric acid replace part of the atoms of hydrogen in the molecules of the cotton, or cellulose, as it is called by the chemists.

If the acids are the strongest that are made and the temperature during nitration is kept low, and the immersion lasts for several hours, the greatest degree of replacement of hydrogen atoms by nitrogen oxide groups takes place; but if the temperature rises or the acid mixture is weak and the time of immersion is short, fewer of the hydrogen atoms of the cellulose molecule are replaced, and by taking advantage of these conditions we obtain cellulose nitrates containing from four to eleven atoms of nitrogen in the molecule, and each of these nitrates possesses different properties, but all of them have, by this treatment, become to a degree explosive, their explosibility increasing with the increase in their nitrogen contents.

It may appear singular that further contact with acid, and especially sulphuric acid, will cause the decomposition of these cellulose nitrates; yet such is the case, and therefore it is necessary, after nitration, to free the cellulose nitrates rapidly and completely from the acids present, which is done by wringing out the mass in a centrifugal machine and immersing the mass in a tank containing a large volume of rapidly changing water, in which the cellulose nitrate is kept in agitation by a revolving feathered wheel; afterwards it is boiled with water which usually contains a small quantity of sodium carbonate.

As, however, the cotton fibre is in the form of capillary tubes of considerable length, this washing and boiling does not suffice to remove the acid from the interior of the tubes; the material is,

SHAPING CHARGES OF GUN-COTTON WITH A BAND SAW

therefore, put into a pulper, or rag-engine, such as is used in paper-making, and pulped to the fineness of corn meal, while at the same time it is washed by a continuous change of water until by chemical tests it is found to be free from acids.

None of the cellulose nitrates before pulping and when dry present any different appearance to the eye from the cotton from which they were made, but they have a harsher feel. They all burn much more readily when ignited, and the higher-nitration ones especially flash off instantly without producing any smoke or leaving any appreciable residue. Unlike cellulose, the cellulose nitrates of lower nitration are soluble in a mixture of ether and alcohol, while the higher ones are not so, but are soluble in acetone. The nitrates soluble in ether-alcohol are known as pyroxylin or collodion gun-cotton, and are used in the manufacture of celluloid, collodion and like substances, while the nitrates of the highest nitration are more specifically known as gun-cotton or military gun-cotton.

It is this latter which has been used for filling torpedoes, mines, and shell, and for purposes of demolitions. To prepare it for use, the pulp from the rag-engine is conveyed to a moulding press and the moulded disks or blocks are taken to a final hydraulic press, where they are fashioned into the desired forms, just as *papier maché* is. As taken from the press these blocks contain from twelve to sixteen per cent. of water, but as sent into the service they contain about thirty-five per cent., which is added by allowing the compressed blocks to soak in a trough of fresh water until they cease to absorb more. If, in providing charges for torpedoes and shells, it is inconvenient to mould the portions for the ogival shaped heads or other parts, these are

readily and without much danger shaped from blocks on hand by cutting them with a chisel or hand saw, or boring with a drill, or turning in a lathe, being careful to keep a stream of water flowing on the gun-cotton during the operations.

When thoroughly dry, compressed gun-cotton may be set on fire, and it burns with considerable vigour; but the writer has repeatedly set on fire blocks weighing several ounces, and when they were well ignited, extinguished them by pouring water upon them. Dry gun-cotton does not explode when ignited, except when confined.

Wet compressed gun-cotton does not take fire until dried. The writer has frequently placed stout boxes of it, containing upwards of 100 pounds, in a fierce bonfire and allowed the boxes to burn through, when the disks slowly dried in layers and ignited on the outside, but would be extinguished by simply rolling them out on the earth. Nor is wet gun-cotton exploded by the impact of a projectile.

Wet gun-cotton is, however, exploded by the detonation of a small amount of dry gun-cotton in contact with it, and the detonation of dry gun-cotton is effected by means of a detonator, or blasting cap, containing mercuric fulminate, fired in contact with it. The explosion produced in this way is an extremely violent one, it has a marked rupturing effect, and can be effected without confinement of the explosive. It is sufficient to place the thoroughly saturated gun-cotton upon the ground, to put on this a small block of dry gun-cotton containing a detonator inserted in a hole in the block, and to fire the detonator by a fuse or an electric current, when the whole of the gun-cotton will be instantly exploded and resolved into gas.

The second typical explosive of this class, nitro-glycerine, is made by slowly mixing pure glycerine with strong nitric and sulphuric acids, being careful to keep the temperature down while the nitration goes on. Here also nitrogen oxide replaces hydrogen in the glycerol molecule, and we obtain, after washing, a liquid which looks like the bland, innocuous glycerine with which we are so familiar (though the commercial nitro-glycerine is usually yellow), but which is poisonous and explosive.

Theoretically, there are three glyceryl nitrates, but the nitro-glycerine with which we are practically acquainted is the glyceryl tri-nitrate. The washing of the nitro-glycerine is more easily accomplished than that of the gun-cotton, yet, perhaps on account of foreign bodies present, its stability is not so well assured. When set on fire nitro-glycerine burns vigorously; if spread out on a surface, it may burn away without explosion, but if the surface with which it is in contact becomes heated, the nitro-glycerine will explode with violence. It is usually exploded by means of a detonator or blasting cap, and it is then instantly resolved into gas. It can be detonated unconfined, but its efficiency, in common with all other explosives, is increased by confinement. As it explodes in direct contact with water, the latter is often used to confine or tamp it, as it is called, when used in blasting.

Nitro-glycerine poisons when it is taken into the mouth, or absorbed through the skin, or inhaled as vapour, and even very small quantities produce violent headaches. It is readily exploded by a blow. It freezes at from 39° to 40° F., and remains in this condition even when exposed to a much higher temperature for some time. When frozen it is exploded only with great difficulty.

Because of the danger attending the liquid state and the great sensitiveness of nitro-glycerine it is converted into a component of a solid mass by absorbing it in a porous material, like infusorial silica, when it is known as kieselguhr dynamite; or a mixture of wood pulp and sodium nitrate, when it is known as lignin-dynamite; or by dissolving pyroxylin in it by the aid of heat, when it is converted into a jelly-like mass, known as explosive, or blasting gelatine. The latter may be further mixed with cotton or charcoal, when it is known as gelatine dynamite. All these owe their

explosive properties to the nitro-glycerine, and the gelatines to the pyroxylin also, contained in them, and they exhibit many of the good and bad quailties of the nitro-glycerine. The explosive gelatine is the most powerful and least sensitive of these nitro-glycerine substances. All, in common with gun-cotton, have been known to undergo dangerous spontaneous decomposition.

Although much longer known and used than the organic nitrates, none of the nitro-substitution compounds have ever been known to undergo spontaneous decomposition, and they offer a greater assurance against the user being " hoist with his own petard " than any of the explosives known. Picric acid, or trinitrophenol, the first member of this class, was discovered by Hausmann in 1788, but the number of the nitro-substitution compounds now produced is very great. Among them may be mentioned the nitro-benzenes, nitro-toluenes, nitro-phenols, nitro-cresols and nitro-naphthalenes, all being produced by the action of nitric and sulphuric acids on substances, such as benzene and carbolic acid, produced in the distillation of coal. None of these bodies explode by simple ignition unless strongly confined, and they are extremely insensitive to shocks or blows; but Berthelot has shown that if a mass is uniformly heated to a certain temperature, which, fortunately, is far above any natural temperature, and which is constant for each body, the substance will explode with great violence.

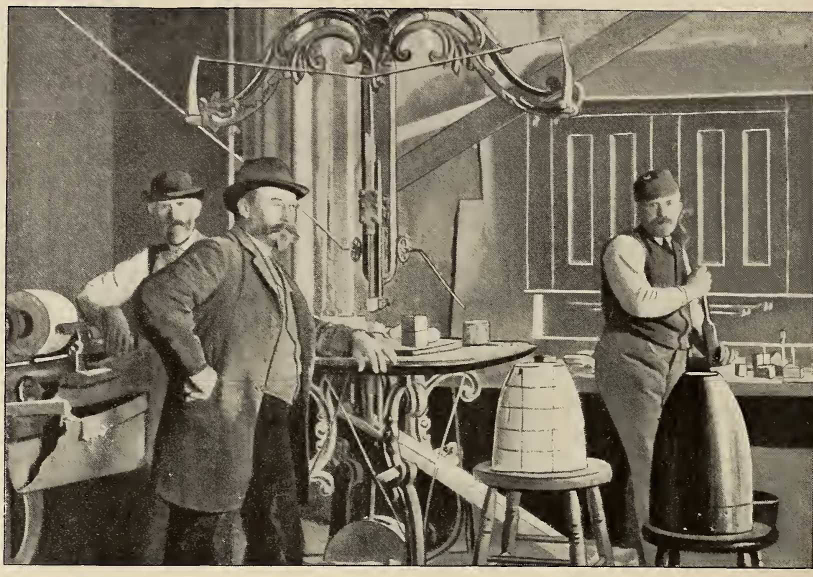
These substances are sometimes used alone as explosives, either in the fused or granulated state, and we have examples of this in melinite and lyddite, which consist of fused picric acid. More frequently they are mixed with oxidising agents, as in ecrasite, which consists of ammonium trinitrocresylate and potassium nitrate; in emmensite, which consists of picric acid, dinitrobenzene and ammonium nitrate; and in joveite, which consists of nitro-phenols, nitro-naphthalenes and sodium nitrate. These explosives are made by melting the nitro-substitution compounds in steam-heated kettles, and then mixing in the finely powdered oxidising agent. They are so insensitive as to require powerful fuses, but they are detonated by strong detonators or gun-cotton primers.

As noted, all of these explosives require an initial charge of mercuric fulminate with which to detonate them. This body, which was the first, and is still the best known, of the fulminates, was discovered by Howard in 1800. It is made by dissolving mercury in nitric acid and pouring the mercuric nitrate thus formed into ordinary alcohol. A violent reaction soon begins, dense clouds of white and then orange coloured vapours are evolved, and then the mercuric fulminate is precipitated out in small, gray, beautifully formed crystals, which are washed with water and stored wet.

This body is exceedingly dangerous. It is very sensitive and explodes with great violence. When dry it is exploded by heat, percussion, concussion, friction, flame or spark. Wet fulminate is exploded even when immersed in water by the explosion of dry fulminate in contact with it. Mercuric fulminate always undergoes a detonating explosion, and, according to Berthelot, it will develop, in contact, the enormous pressure of 360 tons per square inch, and this is developed instantly.

Mercuric fulminate is used in loading primers, caps and detonators. The United States Navy detonator consists of a copper case, 1⅛ inch long by 11-32 inch in diameter, in which are placed 35 grains of dry mercuric fulminate. On the mouth is screwed a copper cap, ⅝ inch long and 12-32 inch in diameter, fitted with a plug made of sulphur and glass. Two copper wires are fused in the plug, the inner ends being connected by a fine wire, composed of platinum and iridium, to form an electric bridge, and the outer ends being left free to connect with a battery or dynamo-electric machine when it is desired to fire it.

As the cap is screwed on the case, the space between is filled with mealed gun-cotton, and, after closing, the whole



CHISELING AND TURNING BLOCKS OF GUN-COTTON FOR CHARGING SHELLS. THE BRASS NOSE OF A SHELL IS SHOWN ON THE RIGHT-HAND STOOL, AND THE CHARGE FOR THIS ON THE LEFT-HAND STOOL AND IN THE LATHE

case is painted with a composition to make it water-tight. Although in the writer's experiments he found that steam-dried gun-cotton can be detonated by three grains of mercuric fulminate, and air-dried gun-cotton by five grains, provided the fulminate is well confined in thin copper cases and the cases are in intimate contact with the gun-cotton, yet thirty-five grains are employed in the service detonator to afford a large coefficient of assurance.

It is well known that if a pile of unconfined gunpowder of considerable size be ignited, it will flash off without doing any material damage to the support on which it rests, although that support may be very frail; but if even a few ounces of gun-cotton, or nitroglycerine and the dynamite made from it, or mercuric fulminate, be placed unconfined upon even a stout support, such as a rock or a piece of steel, and detonated, the rock will be shattered or the steel will be indented.

This difference in effect is explained by the fact that as gunpowder is a mixture of bodies which react upon one another, the chemical change goes on with comparative slowness and the gase evolved are gradually dissipated, while as the other bodies enumerated are chemical compounds which contain all the elements necessary to combustion, the change is one of molecular disintegration, and it takes place so quickly that the resulting gaseous molecules impinge with an enormous velocity upon the supporting body before they escape into the atmosphere. Owing, then, to this difference in the speed of the chemical reaction taking place, the explosives of the gunpowder class are styled low explosives, while the others just enumerated are styled high explosives. The low explosives are used as propellents, and in blasting when it is desired to avoid shattering effects, while the high explosives are employed when a violent shattering of the object attacked is sought.

Nevertheless, we can, by suitable treatment, so change the physical characteristics of gun cotton and nitro-glycerine that they may be used as propellents, and they, thus, become low explosives. The change consists in simply converting them by the aid of

solvents and pressure into dense solids, like hard glue or ivory, and in this way are formed the modern smokeless powders. Thus the powder with which the United States Navy is now experimenting is practically celluloid, which is made by heating pyroxylin with ether-alcohol until a plastic mass is formed, which is then squirted by powerful hydraulic presses into strips of different dimensions. These are dried to remove the solvent.

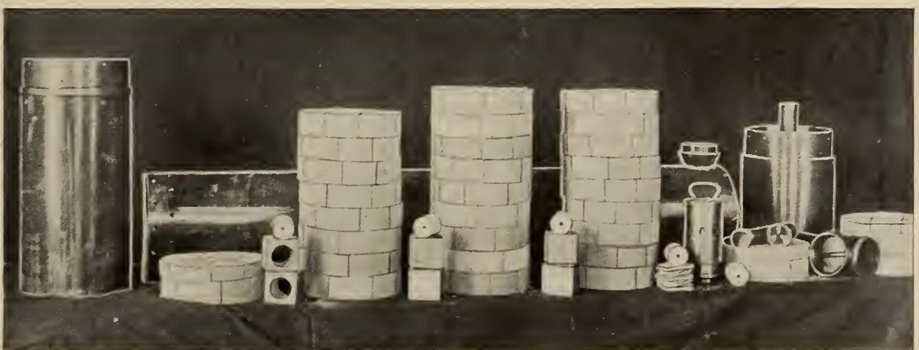
The American naval smokeless powder of 1892 consisted solely of gun-cotton of the highest nitration, and was made by treating military gun-cotton with methyl alcohol to remove any pyroxylin, and then with mono-nitro benzene by which a plastic mass was produced, which was squirted into rods, or rolled into sheets and cut into grains. These were treated with boiling water to remove the nitro-benzene, when the gun-cotton was found to have the hardness and lustre of ivory.

This was the first powder ever produced that consisted of a single chemical substance in a state of purity, and it gave low pressures and imparted high velocities to the projectile, while its permanency is assured by the fact that samples which were exposed for months to toasting in a steam closet and freezing in an underground magazine remain to-day unchanged.

The cordite used in the British Navy consists of a mixture of pyroxylin and gun-cotton with nitro-glycerine, while the ballistite of Germany and the filite of Italy consist of pyroxylin and nitro-glycerine. These are but a few of the mixtures of cellulose nitrates and nitro-glycerine proposed for use, many of them having also oxidising agents, nitro-substitution compounds, and other bodies as constituents.

The use of the high, or rupturing, explosives for naval purposes is confined to the blowing-up of obstructions, such as booms and chains, to the filling of mines and torpedoes, and to the loading of shells. Gunpowder has been used with effect for all these purposes, but the greater power and speed of reaction of the high explosives render them more efficient, and they are employed wherever this can be done without unnecessary danger to the user.

Although explosive gelatine, as fired in mines, is about 5.6 times as efficient as the same weight of gunpowder, it, in common with other nitro-glycerine explosives, has exploded when stored in magazines, while besides, it can be exploded by shock and impact, and thus it is unsuitable to be stored on board ship or to be fired in shells. The less powerful, but less sensitive, gun-cotton and nitro-substitution compounds, and more particularly the latter, are free from these objections, and wet gun-cotton is now altogether used for naval mines and torpedoes, a small priming charge of dry gun-cotton and a fulminate detonator being used with which to fire the wet charge, and these elements are care-



CYLINDRICAL CHARGES OF GUN-COTTON WHICH HAVE BEEN SAWN FROM SERVICE BLOCKS

fully stored in widely separated places until the missile is wanted for use, while the amount of dry gun-cotton on hand is always kept at a minimum and frequently rigorously tested.

The limited range of even the best of torpedoes; the fact that torpedo-boats can never expect to reach the enemy except by stealth; that this difficulty is continually increasing with the increase in the speed of battle-ships and cruisers, the perfection of search lights, and of rapid-fire, high-powered guns; and that, in any event, a torpedo attack is in the nature of a forlorn hope, makes it inevitable that some more efficient method of reaching the enemy with high explosives must be employed, and this is to be found only in gun fire.

Two systems of gun fire have been proposed and tested. In one of these a low-pressure gun of long bore is used, and the propellent is a slowly expanding, compressed gas, as is the case with the pneumatic guns on the United States dynamite cruiser *Vesuvius*. In the other, the regular service gun, service powder and service pressures and velocities are used to project the explosive-charged shell. Evidently, as the projectile from the pneumatic gun has a much more limited range and a lower velocity than the projectile from the gunpowder gun, the latter system is the more effective, and especially as its projectile has great power of penetration, which is an essential condition of efficiency.

It is true that large charges of high explosives may be thrown with pneumatic guns while the charges from gunpowder guns of the most-used calibres will be comparatively small: but the effect produced by the latter after penetration within a ship or the walls of a fort, or even in earth, is vastly superior to the superficial explosion of the former and larger charges. How great this difference is may be more fully realised by considering the results attained in actual experience.

Among the many accidents which are on record, one of the most notable is that of the explosion of 55 tons of blasting gelatine which was being unloaded from a railway train at Braamfontein, 300 yards west of Johannesburg, in South Africa, on February 19, 1896, and which was exploded by an end-on collision. The result of the explosion of this enormous quantity of one of the most powerful explosives used was to produce a crater 300 feet long, 65 feet wide, and 30 feet deep in soft ground; or, taking a cubic foot of earth as weighing 100 pounds, the superficial explosion of this 55 tons of explosive gelatine excavated about 30,000 tons of soft earth.

Besides this, there was a total destruction of all buildings within a radius of 330 yards, while from that distance to 660 yards all the buildings were shattered, and the roofs were battered in up to about 1000 yards; but these buildings were built chiefly of corrugated iron and mud, and therefore were of a most unsubstantial character.

On the other hand, we have the blowing up of the Hudson river Palisades at Fort Lee in 1893, when the explosion of 2 tons of dynamite, placed in a chamber in the rock, brought down 100,000 tons of rock; the blasting at the Dinorwic Quarries, Lamberis, in the same year, when 2½ tons of gelatine-dynamite, placed in chambers in the dyke, overthrew 180,000 tons of rock; and the destruction of the famous Talcen Mawr in 1895, when 7 tons of powder, poured into two shafts, dislodged a mass of rock computed to weigh from 125,000 to 200,000 tons.

From this we find that the dynamite on the interior at Fort Lee was over ninety times as efficient as the explosive gelatine on the surface at Johannesburg, while the powder at Talcen Mawr was over forty-two times as efficient. It is, hence, not surprising that the superficial explosion of the 300-pound charges of gun-cotton thrown by the *Vesuvius*' guns at Santiago during the late war between the United States and Spain, produced no serious structural damage, and simply harassed the enemy by their frightful reports, which occurred at infrequent intervals and unexpected times.

Even this would have a military

value, but for the fact that gun-cotton and nitro-substitution explosives can be, and repeatedly have been, used as shell charges for service guns. When gun-cotton is so used, the material is not only well wet with water to render it insensitive, but it is cut into small masses, which are coated with a waterproof composition, and then these pieces are packed in the shell, surrounded by a mixture of paraffine and carnuba wax, which is poured in hot and allowed to congeal. The mass is exploded by a dry gun-cotton primer and fulminate detonator. Many shells so loaded have been successfully fired with good effect; but, unfortunately, no one seems informed as to how they will behave after they have been stored in the tropics and in cold climates and the charge has become broken up by the expansion of the inclosed water, as would inevitably be the case.

Fortunately, the nitro-substitution explosives are free from liability to change through changes of temperature, for when manufactured they are heated to temperatures far above any occurring in nature, and, as used, they are anhydrous solids, and therefore unaffected by freezing temperatures. The shells are filled by warming the material in a steam-jacketed kettle until the explosive becomes plastic and then ramming it into the shell, where it sets to a rigid solid, which does not "set back" when the projectile starts, as gunpowder does, nor does it rotate in the shell as the latter takes the rifling. Many shells so loaded have been successfully fired, and, in fact, it is said that France has many shells loaded with melinite stored in her magazines, while Great Britain has issued shells filled with lyddite to the Channel Squadron, and the United States Naval Bureau of Ordnance has for several years past been conducting experiments with joveite at Indian Head, Md.

Having proved, by firing common shell, loaded with the various explosives in wooden chambers, that the destructive effect of joveite was greater than that of gunpowder, smokeless powder, or gun-cotton, the United States officials proceeded to fire joveite-filled shells from service guns until on November 3, 1897, a 10-inch Carpenter armour-piercing shell containing 8.25 pounds of joveite was fired with a velocity of 1860 foot-seconds at a Harveyised nickel-steel plate 14.5 inches thick, when the shell passed completely through the plate and burst on the farther side. Only a gunpowder fuse was used, thus eliminating all the danger to which a detonating fuse gives rise.

In a second round on the same day, a 10-inch Midvale semi-armour-piercing shell, containing 28 pounds of joveite, was fired with a velocity of 1925 foot-seconds at a point on the armour for the new United States battle-ship *Kentucky* where it was 16 inches thick. The shell contained no fuse whatever, but it penetrated the plate to a depth of 12 inches and exploded by impact. The plate was broken through at previous cracks and but one piece of the shell was recovered. This was a portion of the base plug which had been sheared longitudinally, and the severity of the explosion was indicated by the fact that no such shearing effect had ever before been observed in shells exploded at this proving ground. All of these firings were conducted without an accident of any kind, except the setting fire to a quantity of the explosive by dropping an incandescent match upon it.

Nevertheless, the United States authorities were deterred from the adoption of these shell charges by accounts of accidents in other countries, which were claimed to be due to the formation of a sensitive compound through the action of the explosive on the walls of the shell, though it was obvious that this could be prevented by the simple expedient of coating the walls of the shell with an inert asphalt varnish. However, the writer is convinced that navies hereafter will not only be provided with smokeless powder for their guns, but also with high-explosive charges for their shells, for the armour-piercing shells are now so strong that a full charge of gunpowder cannot burst

them, and these very expensive projectiles would thus be no more efficient than solid shot.

It is true that the gunpowder-filled shells produced a marked incendiary effect both at Manila and at Santiago, but the nitro-substitution compounds are equal to gunpowder in this respect when exploded by a gunpowder fuse. Yet if all inflammable material is to be removed from ships the incendiary characteristic will not count in the future as it has in the past. From all experience it seems assured that nitro-substitution compounds are the logical successors of gunpowder for charges for shells, to be thrown at high velocities from powder guns.

THE EVOLUTION OF THE MACHINE TOOL

From an American Point of View

By Professor C. H. Benjamin

LIKE all other accomplishments of modern civilisation, machine tools in their present forms are the result of a process of slow development. A machine does not spring full-fledged into being, but is gradually differentiated from the original type, gaining here and there a useful member, and losing here and there a superfluous one, illustrating the survival of the fittest and adaptation to environment as clearly as the horse or the monkey.

Progress in the evolution of machines has not been uniform, but intermittent. Occasionally a Watt, a Stephenson, a Maudslay or a Sweet has given a sudden and marked impulse to design, cutting loose from tradition and showing the originality of genius. But most designers of machinery are copyists; they work with scissors and paste, so to speak, and not with the pen. They are adepts in spying and seizing upon the good features of existing designs and adapting them to the problem at hand, but are entirely destitute of original ideas. The genius wipes his slate clean and begins anew with a design of his own, some radical departure, some step in advance.

The earliest locomotive was but an assemblage of a pumping engine, with its clumsy walking-beam, a Cornish boiler, a barrel of water, and a truck on wheels. But when Stephenson built *The Rocket*, he abandoned all these and gave to the world the prototype of the modern locomotive.

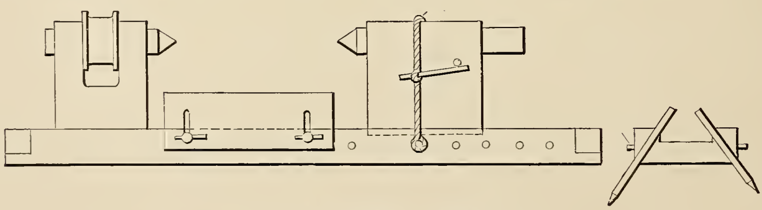


FIG. I. A LATHE 700 YEARS OLD

Every designer is more or less a slave to material, using one set of lines for

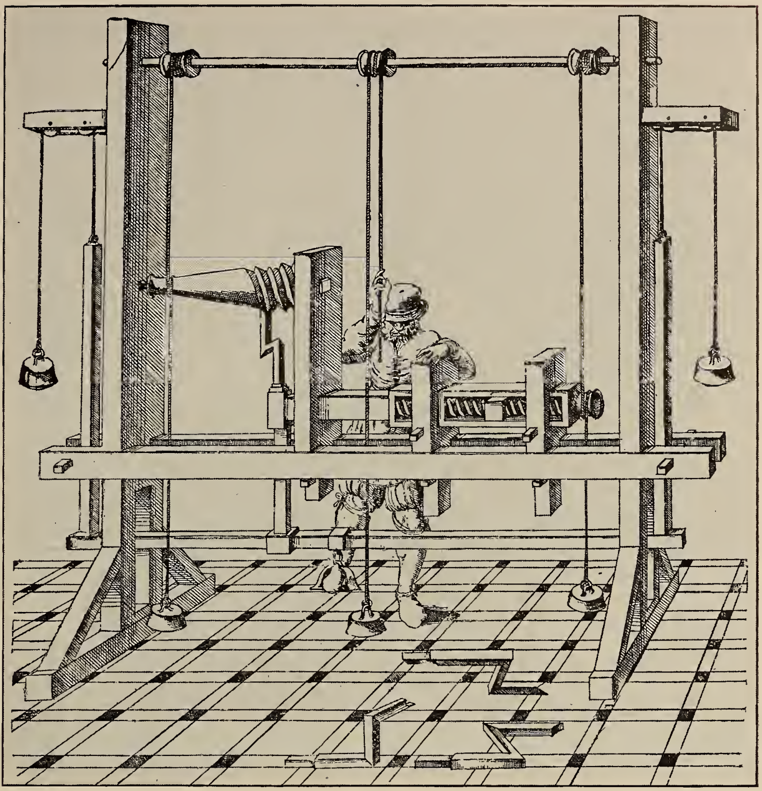


FIG. 2. A SCREW-CUTTING LATHE OF THE SIXTEENTH CENTURY

wood, another for steel, and yet another for cast metal. In the first beginnings of construction man turned naturally to the material which was most convenient and most readily shaped with the rude tools at his command; the limb of a tree or a forked root was fashioned for his plough, the hollow stone for his mill.

So in the earliest machine tools of which we have any knowledge, we find wood used for a framework, because wood was a material easily shaped. The rectangular outlines, the framing and bracing peculiar to wood construction were perpetuated for long afterwards in cast iron. Where wood lacked weight and stability, the early constructor had recourse to stone, and many a lathe or planer had its slender iron ways bolted to blocks of granite for a bed.

With the general introduction of cast iron as a material of construction, there came naturally a revolution in design. In some respects this revolution was not a desirable one. Although the old wooden frames were somewhat stiff and ungainly in appearance, they were free from ornamentation. No wood-carving was attempted, for wood-carving was expensive, and the granite beds of the old machines were entirely destitute of architectural embellishment.

But cast iron fancy work is cheap, and the advent of this material was followed by an epidemic of meretricious ornamentation, and a riotous indulgence in panelings, mouldings, vines, fruit and flowers. That this craze for the rococo in cast iron is not confined to the past generation, or to the machine shop, is evidenced by that nightmare of design, the modern parlour stove, with its Louis XIV. legs, Gothic body, and Hindoo sky line.

Paneling is a legitimate form of con-

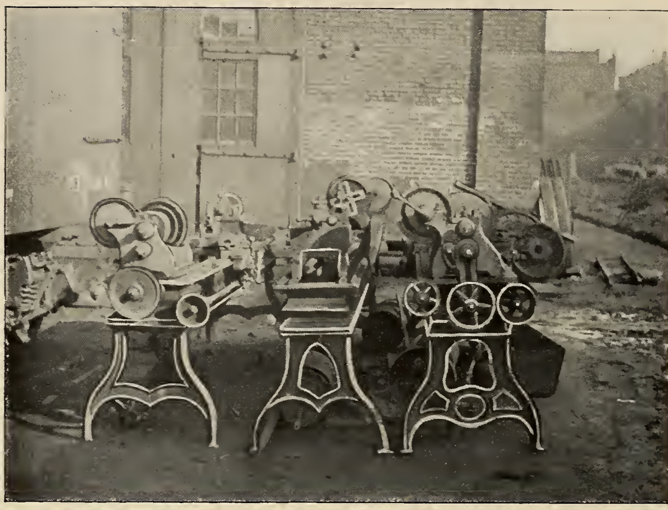


FIG. 3. SOME THINGS TO AVOID IN LATHE DESIGN

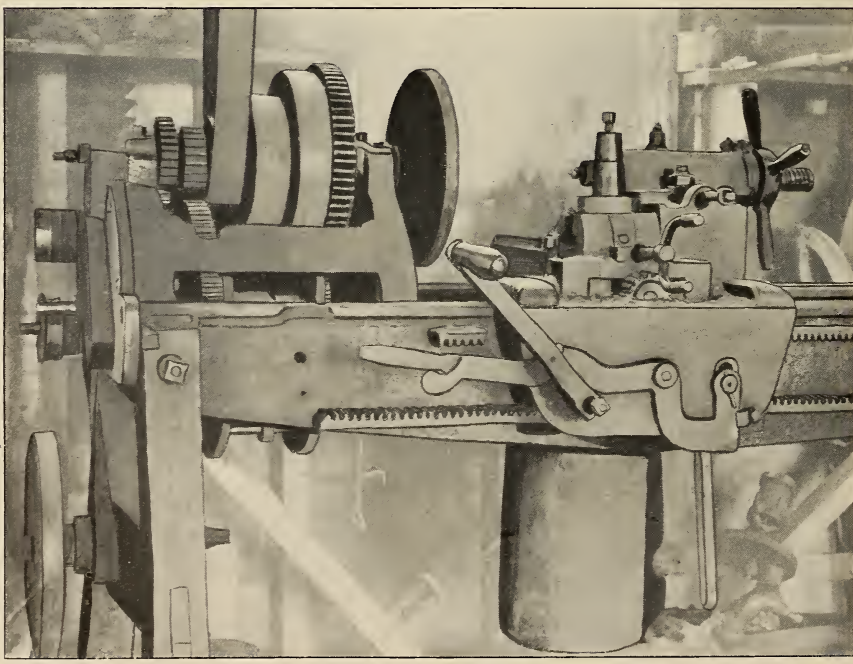


FIG. 4. AN OLD-TIME LATHE WITH WOODEN LEGS

struction in cabinetmaking to prevent warping and to conceal the shrinkage of the wood. The shrinkage of cast iron, however, can hardly be prevented by such means, and one can see in them only an absurd and unreasoning imitation.

In architectural construction, flutings, mouldings, and conventional representations of fruit, flowers, or foliage, if wisely used, are pleasing to the eye and entirely appropriate, since architecture has the twofold mission of cultivating the useful and the beautiful, of furnishing a shelter for man and his belongings, and of making that shelter a harmonious addition to the landscape. The fact that each moulding and each bit of tracery represents the patient and careful labour of a skilful artist, adds yet more to their interest.

But ornamentation of this character is entirely out of place on the machine tool, whose only excuse for being is its utility. The only beauty which a machine shop may possess is that of light and cleanness, and utility. The machines themselves may then best harmonise with the "landscape" by being efficient, convenient and easily cleaned.

The very cheapness of cast iron decoration makes it seem vulgar and commonplace, and relegates it to the realm of the calico print and the cheap chromo. The same false idea of beauty led the early designers of machinery to resort to bright colours, to varnish, and to brilliant polish. A vivid green ground, with yellow stripes and scarlet flowers, or some equally startling combination, was nothing unusual in engine, as well as machine, construction forty or fifty years ago, while varnish, shining brass, and polished iron contributed their share to the blaze of glory.

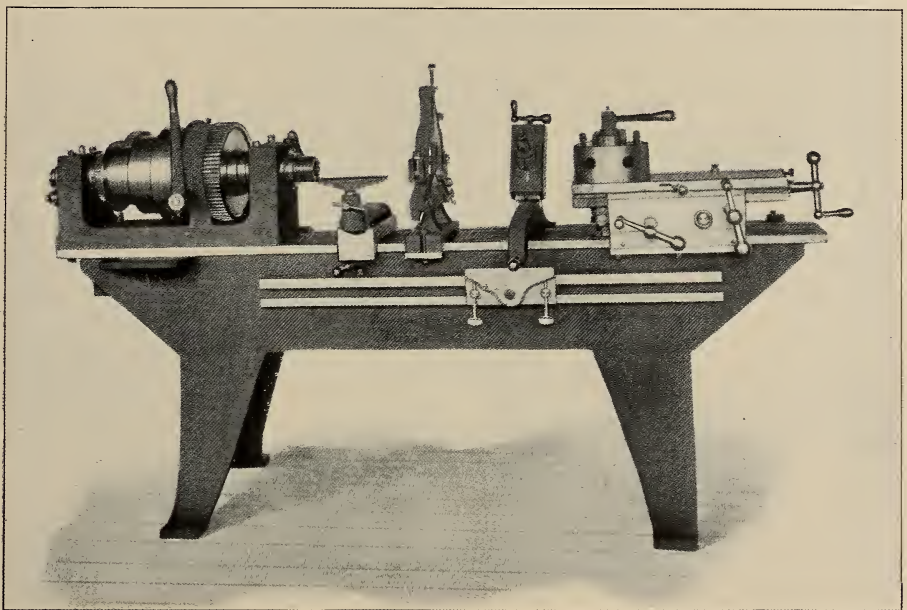


FIG. 5. A MODERN LATHE OF THE LATEST TYPE

Every ledge and projection on a machine tool is but a place for dust and grease to form an unholy alliance; every bright surface of paint and varnish invites bruises and scratches, and sweaty hands soon dim the lustre of polished metal. A few years of service effectually ruins such holiday attire. The sober garb of modern machinery is meant for wear, like the blue denim

of the workman, and looks almost unchanged after years of use.

The lathe is one of the oldest and most useful machines; but, strange to say, its development has been the least marked, and to-day, in many instances, it shows a survival of much that is incorrect in principle and grotesque in appearance. The ancestor shown in Fig. 1 claims to have been in service in the Levant 700 years ago. It is certainly chaste and simple in design, and a good example of the absence of metal as well as ornament.

The screw-cutting lathe of the sixteenth century, Fig. 2, shows many evidences of inventive ability, but could hardly have been a successful machine. The numerous joints, the elasticity of the frame, and the eccentricities of the motive power must have severely tried the religious principles of the old Huguenot in charge.

The first Putnam lathe built in the United States, in 1835, had a wooden bed and legs, and the slide rest moved on thin iron ways bolted to the bed.

In Northampton, Mass., there was recently an old lathe of 36-inch swing, having a wooden bed with iron ways, and at North Chelmsford, in the same State, there is, or was, a 48-inch lathe having its ways bolted to a bed of granite.

In Fig. 4 is shown an ancient lathe which is to-day doing service in an Ohio shop. The bed consists of two parabolic girders of cast iron, bolted together, and the legs are wooden. The "back gears" may be seen peeping from underneath the headstock. Especial attention is called to the tailstock and its screw, to the feed mechanism on the apron, and to the weight hanging from the carriage. In fact, this lathe is a curiosity, and will repay careful study.

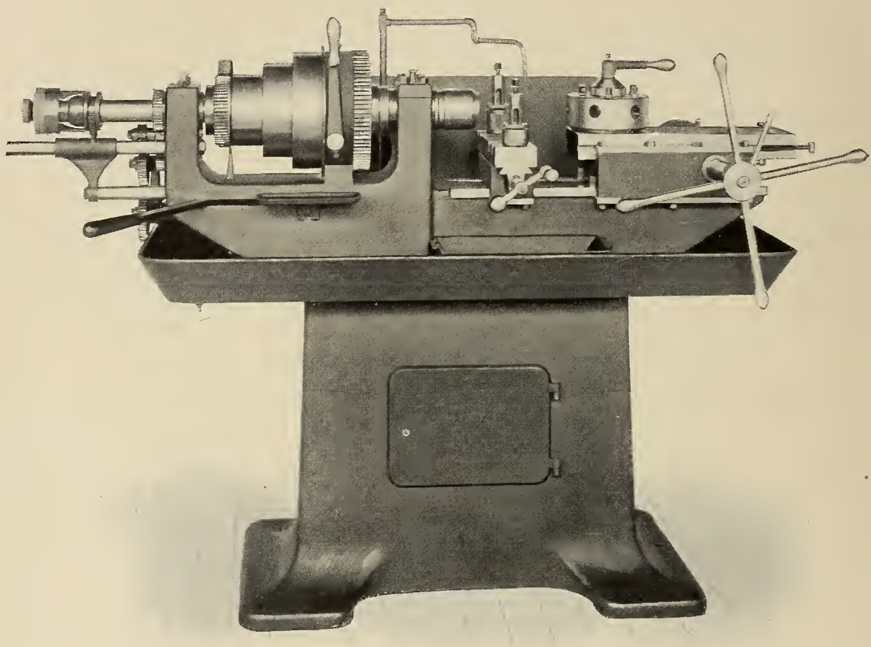


FIG. 6. CABINET DESIGN FOR MACHINES OF MODERATE LENGTH

It is a cardinal principle in machine design that the metal shall be distributed in such a way as to best resist the stresses which come upon it. Where exposed to tension or compression, the

FIG. 7. AN OBJECT LESSON IN POOR PLANER DESIGN

metal should lie in straight lines along the axis of a stress; when subjected to twisting, the cross-section should be circular; and for resistance to bending, the outlines should be those of the parabola, or ellipse, as giving the greatest strength with the least metal.

The bed of a lathe is a beam, exposed to bending strain from its own weight and the thrust of the tool, and to twisting on account of the unevenness of its supports. The beds of most lathes have been, and are, two shallow I-shaped girders, connected at intervals by cross ties, and offering some resistance to bending, but almost none to twisting. In only one or two instances has any attempt been made to employ a box section or any approximation to a cylindrical form.

The legs, which are the points of support for the bed, should be a certain distance from each end to reduce the

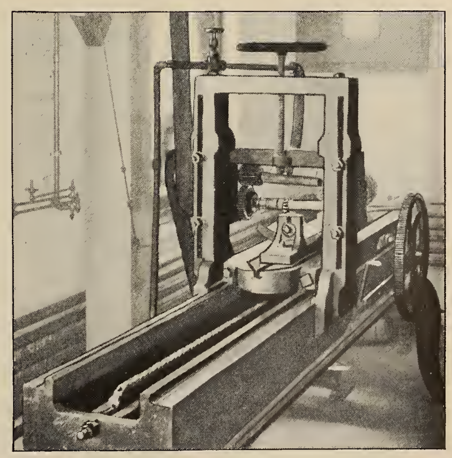


FIG. 8. MILLING MACHINE WITH CHAIN FEED

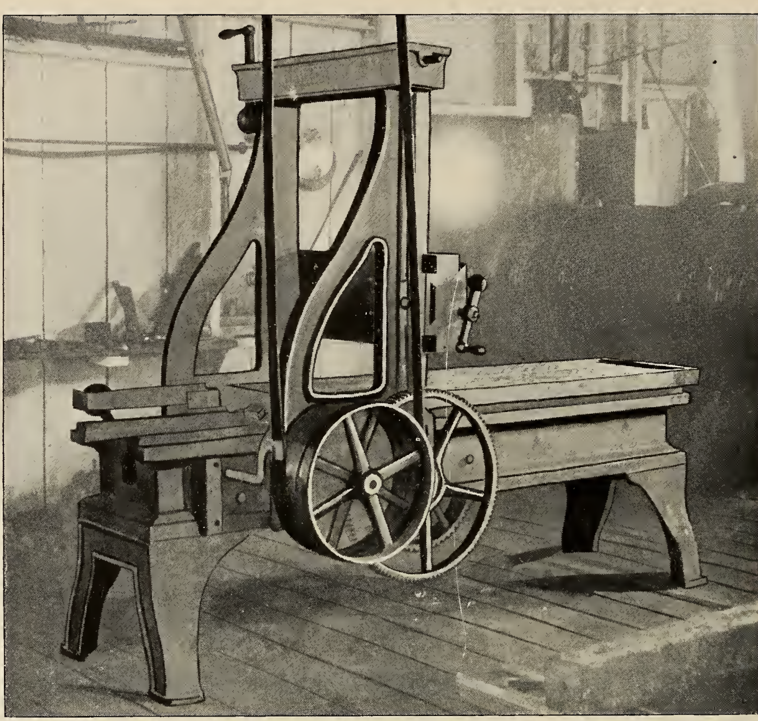


FIG. 9. AN IMPROVED TYPE OF PLANER

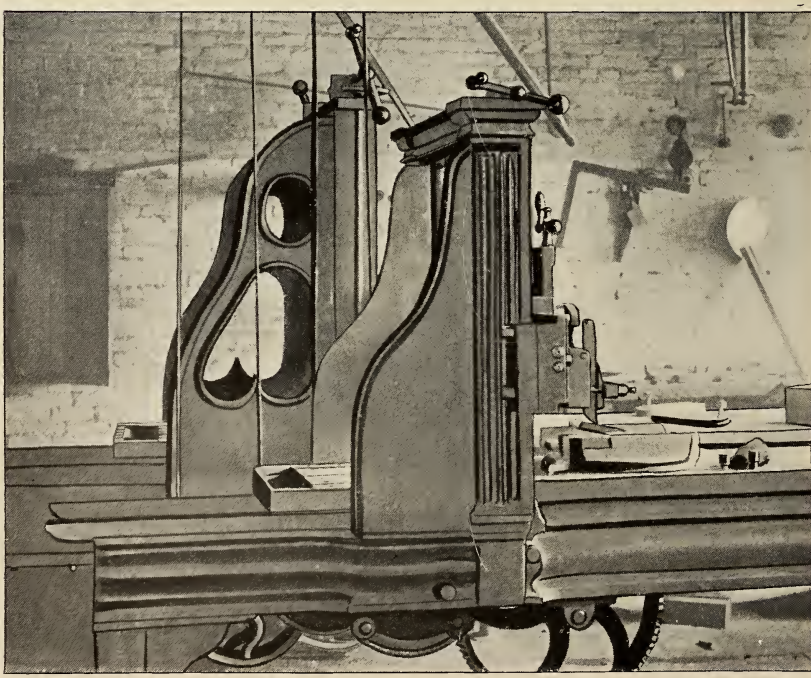


FIG. 10. AN ANTIQUATED DESIGN

length of bed exposed to bending. As a matter of fact, however, nearly all lathes have legs at the extreme ends of the bed, and in some instances the legs are spread at the bottom.

In some cases the beds are paneled; in others, they are decorated with ogee curves and intricate mouldings, while the fancy of tne designer has seemingly run riot in devising strange and uncanny shapes for the lathe legs. Perhaps Fig. 3 will give the reader as good an idea of what to avoid in lathe design as several pages of description could do. The three lathes shown had just been taken out of a railway repair shop when the photograph was taken. When machines are thrown out of a repair shop they are, indeed, forsaken.

Within the last two or three years there has been a noticeable improvement in frame design. Gaudy paint and varnish have long been abandoned; no metal surfaces are polished, except for bearings, while the unsightly mouldings and meaningless curves are giving place to plain surfaces and simple lines. In Fig. 5 is shown a modern lathe of the latest type of development. Contrast its strength and simplicity with the absurdities shown in Fig. 3.

Perhaps better than legs of any sort is the cabinet for all machines of moderate length, Fig. 6. It takes up less room, gives greater stability and less tendency to twist the frame, and, lastly, furnishes a convenient receptacle for gears and tools.

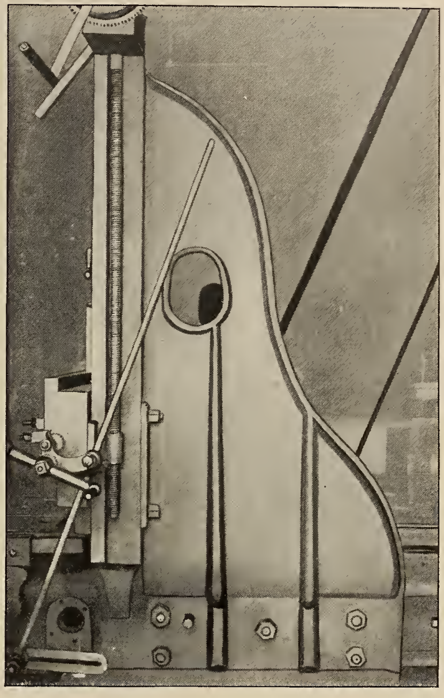


FIG. 11. A FREAK IN PLANER HOUSINGS

One is inclined to regard the milling machine as a comparatively modern tool, and to look to the future for its development rather than to the past. Fig. 8 shows a machine still in use in a certain shop which was old when the present owner acquired possession. This tool has many of the characteristics of some machines of to-day, but the chain feed and the general style of architecture stamp it as a relic.

Probably the oldest planer in America is one owned by the Silver & Gray Company, of Nashua, N. H. It dates back to about 1836, has iron ways, chipped and filed, and fas-

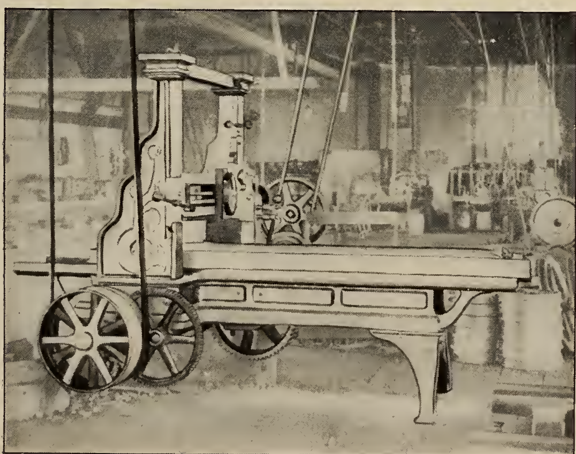


FIG. 12. OBJECTIONABLE ALL AROUND

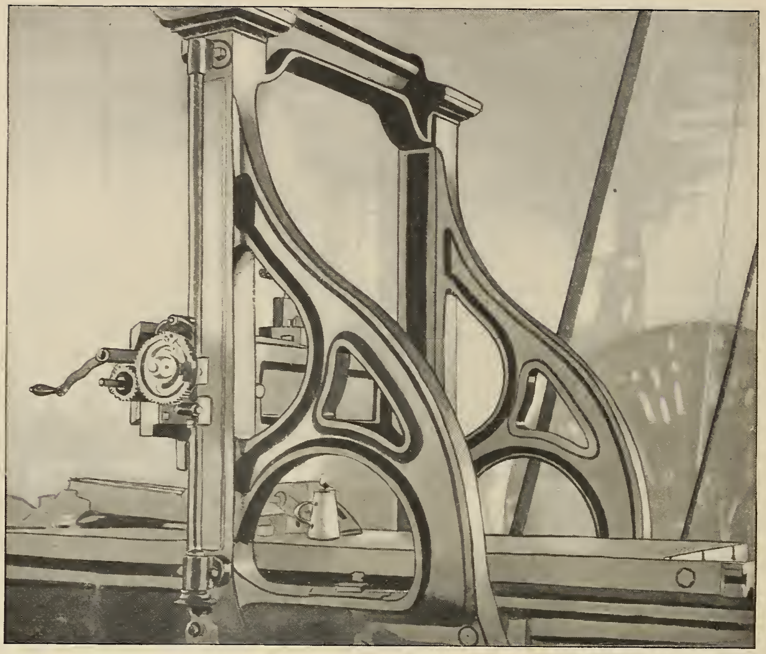


FIG. 13. "SPENCERIAN" UPRIGHTS

tened to a granite bed, and the platen is driven to and fro by a chain. There is one planer running to-day in a Cleveland shop whose platen is moved by a series of chains, similar to those used on chain hoists, and winding over drums at each end.

FIG. 14. A STUDY IN SCROLLS

The iron planer shares with the upright drill the questionable honour of affording the best field for eccentricity in design. The Louis XIV. leg, with its reversed curves and luxuriant decorations of fruit and flowers, has survived all the ups and downs of history, and is in evidence to-day on chairs, pianos, parlour stoves, and even on iron planers, as evidenced in Fig. 7. As the function of a planer leg is not walking, but standing still and supporting a weight, the sprawling double curve is as useless as it is fantastic.

From the purely utilitarian standpoint this style of support has its disadvantages, for if the reader can imagine a machinist possessed of a somewhat irritable temperament and numerous corns, hurriedly rushing around the end of a planer like the one in the cut, he can also imagine the consequences.

Fig. 7 shows, as well, the use of curved lines and mouldings in the bed, and the evident attempt to imitate rosewood cabinets in cast iron. The pro-

jection of the ways at the end, without adequate support, is in marked contrast to the sturdy frames of to-day, as shown in Fig. 17.

Fig. 10 shows clearly these peculiarities of the bed in planers built a generation ago, and the curved arms of the driving gear furnish another clue to the age of the machine.

In Fig. 9 the reader may see a step forward in the evolution of the modern frame. The legs are losing their scroll-like character, and the bed has more of the girder and less of the piano in its composition. The moulding dies hard, and is still there, but in a less conspicuous form.

It is in the housings or uprights of planers that the fancy of the designer has made its wildest flights. The reversed curve again makes its appearance, and it is an element of structural weakness. The slender tops of the housings shown in Fig. 10 would vibrate and sway under a heavy cut, like a sapling in a gale of wind.

Classic architecture has apparently furnished some of the ideas which flourished at the sides of ancient planers. In Fig. 10 may be seen the fluted column, the elaborate capital and the reversed curve in several degrees of ugliness.

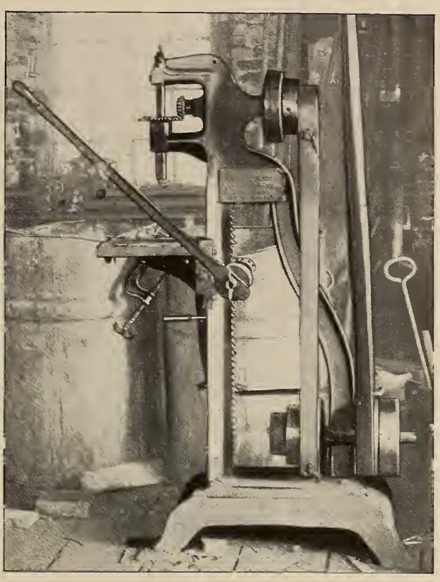


FIG. 15. A LEVER-FEED DRILL PRESS OF UNCERTAIN AGE

The perpendicular style of treatment is illustrated in Fig. 11. What the hole is for in the upper part of the housing is one of those things that no fellow can find out, for a worse place in which to cut a hole could not have been chosen. Some of the older planers have, instead of the panels seen here, a series of lancet-pointed windows of varying heights, in the early English style, and the outline of the housing is made to conform to these without regard to the laws of strength and stiffness.

In Fig. 13 we see an upright, designed according to what may be called the Spencerian system,—a series of easy, flowing curves that betoken the hand of an expert in chirography, perhaps, but a tyro in machine design. The lighted lamp on the platen

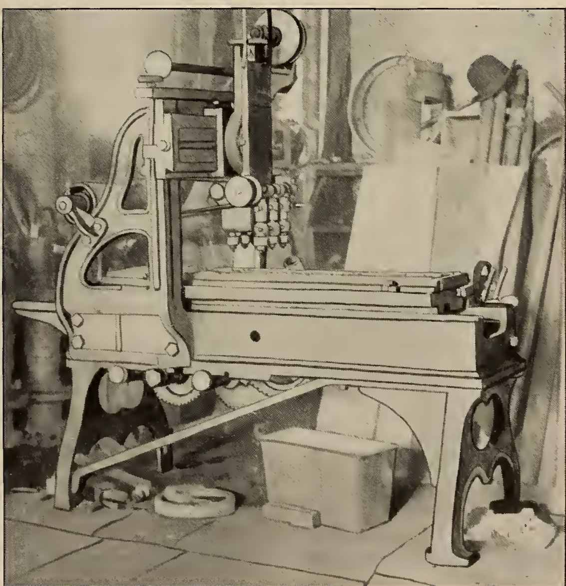


FIG. 16. A STEP IN THE EVOLUTION OF THE UPRIGHT DRILL

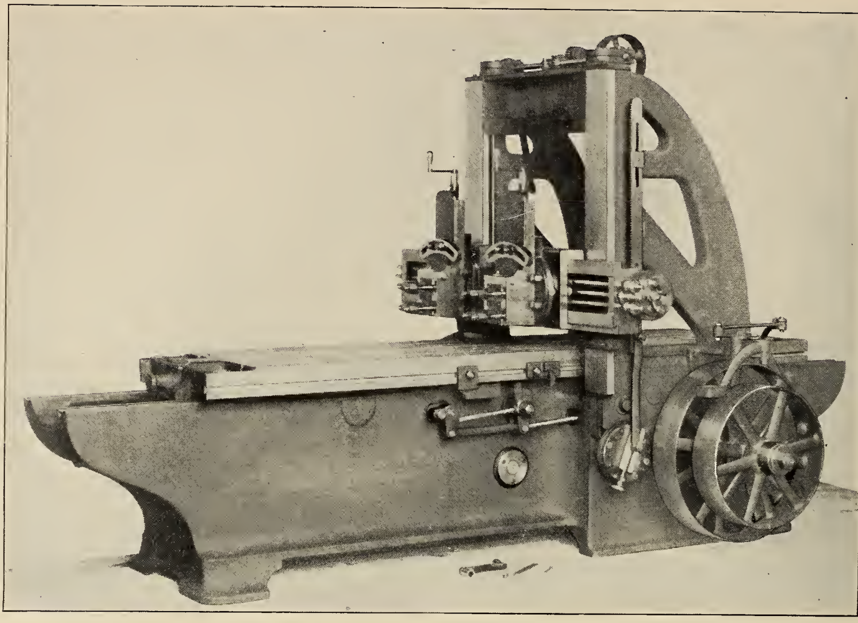


FIG. 17. A MODERN WELL-DESIGNED PLANER

shows that all this beauty was born to blush unseen, except by lamplight, and illustrates some of the difficulties of obtaining photographs for an article like this. If it were only possible to reproduce in colours the appearance that these old machines probably presented in their early days, when resplendent with paint and varnish, the contrast of old and new would be still more striking.

In Fig. 12 are seen the paneled bed, the overhang, with its slender brace, numerous mouldings, and a triumph of decorative art in the scroll which adorns the side of the housing. We are thus led up gradually to the supreme effort shown in Fig. 14, where the scroll was evidently the main object of design, to which the outline of the housing was made to conform as closely as possible. The architect, for such is of right his title, was accustomed to crown his structure with a sort of triumphal arch at the top rail, bearing the names of the builders on its entablature (see Fig. 7). To point the moral and adorn the tale, the writer would call attention, without comment, to the modern planer shown in Fig. 17, and leave the reader to draw his own conclusions.

In biological evolution we have heard much of missing links in the chain of development. We are taught that saurians change to birds and monkeys to men. Fig. 16 shows how planers change to upright drills, and supplies the missing link in the mechanical evolution. Particular attention is called to the gradual disappearance or absorption of the rear leg during this process, reminding us of the gradual shortening of the simian tail. If adaptation to environments is also a phase of mechanical evolution, the environment of this machine is calculated to effect some startling changes.

Of all the tools at present in use the drill, undoubtedly, dates back to the most remote antiquity. The writer has in his possession a stone hammer taken from one of the kitchen-middens of Denmark, and, doubtless, a contemporary of Abraham. The hole for the handle is so straight and true as to bear evidence of having been drilled with some form of rotary tool. The old-fashioned bow-drill was in existence at the dawn of history, and no one knows its origin.

Like the housings of the planer, the

frame of the upright drill has suffered from well-meant attempts of ambitious designers to "hold a mirror up to nature." Some of these geniuses evidently went to the banyan tree for models, others had dreams of megatheriums and iguanodons, while one inventor had the courage to catalogue his drill press as designed in "pure Tuscan."

Fig. 15 shows a lever feed drill press now in use in one shop, but of uncertain age. It is known, however, that it was in use prior to 1861. The frame bears no resemblance to those of modern machines. The base is adapted from the kitchen range, and the remainder of the frame is of the ribbed type of construction. Reference to Fig. 9 will disclose a strong family resemblance to the double-curved housings of the early planer, which bears out the theory of evolution. The prominence of the name-plate shows that the general result was regarded with satisfaction by those financially interested.

In Fig. 18 may be seen another drill from the same shop, but of an advanced type of development. Power feed has made its appearance, and back gears are very much in evidence, as may be seen from the tooth-marks on the cone belt. The column has now come to stay, as yet unaccompanied by any minor shoots at the rear, but decorated, as usual, with classic fluting. Revolution of the table around the column gives vertical adjustment by means of the screw. The design is symmetrical, but top-heavy, and the ribbed sections do not harmonise with the column. This machine, however, is chaste and graceful in design, compared with some that are advertised to-day in the columns of technical journals.

We will go again to a railway repair shop to see the weird and grotesque in frame design, as shown in Fig. 19. This is a slotting machine, rather than a drill, but the principle, or rather, the lack of principle, is the same. The frame wanders aimlessly from shaft to counter, and from counter to spindle, "and, like a wounded snake, drags its slow length along." The general result reminds us of that favourite pastime of boyhood, "drawing a pig with your eyes shut," when the relations of eyes, ears and tail to the main body were not much more confusing than the relations of parts in the present example.

It is a relief to turn from this to Fig. 20, showing the frame of a modern vertical milling machine. The frame in Fig. 19 is homely, because the metal is not put in the right place to secure strength and rigidity. The frame in

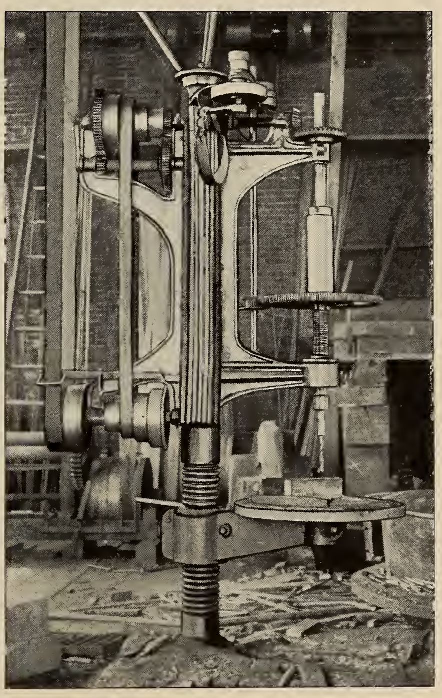


FIG. 18. AN ADVANCED TYPE OF DRILL

Fig. 20 is handsome, because the metal is in the place to do its duty. The substitution of the single round column at the rear for the meaningless aggregation of curves usually seen in upright frames, gives harmony to the design.

If we compare existing types of machines with those now obsolete, it is easy to discover the general trend of development. From year to year there has been an increase in the complexity of detail, accompanied by greater simplicity of design. This may seem para-

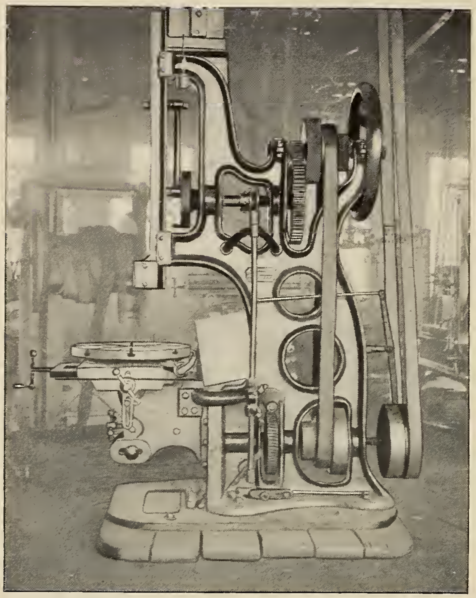


FIG. 19. A GROTESQUE FRAME DESIGN

doxical, but it means that as machine, become more automatic in their actions —as they do more and the man less,— they necessarily require a greater number ot parts; on the other hand, there is greater simplicity and directness in the individual operations, and the different parts are better adapted to the work they do and to the stresses they withstand.

American machines are often more convenient and more rapid in operation than those of other countries. What many of them lack is greater rigidity and freedom from vibration. The gradual abandonment of legs on machine tools and the substitution of cabinets will bring about an improvement in this direction.

The illustrations which accompany this article show a slow but sure advance in the artistic treatment of machine design, if such a term is admissible. Machines are looking less like Greek temples and Gothic cathedrals and more like working machines. Ornament is a thing of the past. The difference between modern battle-ships and the old-fashioned ships-of-war, with their high poops and grotesque carvings, is but another illustration of the same tendency.

And what of the future? It is safe to say that the next hundred years can hardly show such changes as have occurred during the present century. Machines will improve in strength and stability, but, above all, in convenience and in capacity. It is probable that the machine shop of the twentieth century will contain mostly special tools. The lathe, as a lathe, will disappear, and its place will be taken by the turret lathe or the automatic screw machine on small work, and by the vertical boring and chucking machines on large work.

The planer is gradually yielding ground to the milling machine, while the latter will, undoubtedly, be differentiated into special types for special operations. The upright drill of the present generation is likely to be replaced by the radial drill, with its greater convenience and range of work.

There are many shops to-day which contain mostly special machines, each one adapted to its own particular operation, while the general types of planer, lathe and drill are conspicuous by their

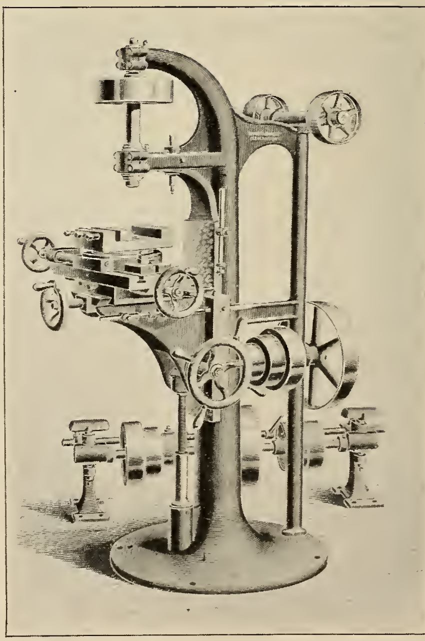


FIG 20. A MODERN VERTICAL MILLING MACHINE

absence. In the future there will be many such shops.

Electricity, as applied directly to machine tools, is, moreover, destined to play an important part in their development. Machines will no longer be slaves to the belt and the line shaft, and this freedom from restraint as to location and connection will make development more easy.

RESPONSIBILITY

By W. D. Wansbrough

WE have all heard occasional exclamations of impatience directed against certain persons, to be found in every large concern, who perform no visible work, and whose time seems to be mainly devoted to the enviable occupation of "sitting in their offices." It is a further trespass upon the rights of the "bona-fide working man" that not infrequently a seemingly unreasonable share of the profits of the establishment is diverted from its natural destination and wasted in keeping up large, and sometimes palatial, residences for these supposedly noneffective individuals. Let me hasten to add that this uninformed and hasty judgment is not so commonly met with now as formerly, which is a proof of the spread of education and common sense amongst workmen.

Premising that what I am going to say will be the merest commonplace to a large proportion of readers, let me, for the especial benefit of our younger men, endeavour to ascertain the reason why wages, as the reward of labour, are so unequally distributed—why one man is paid for his services, five, ten, fifty or a hundred times as much as another; and, again, why the hardest and least agreeable kind of toil is usually paid for at the cheapest rate. Experience tells us that this is commonly the case, but reason does not at once supply us with the explanation.

There are some trades, as, for instance, the manufacture of phosphorous matches, or the glazing of pottery, in which, through no fault of their own, the workers are slowly but surely drawn into the grasp of a ghastly disease; there are others, as the manufacture of white lead and of some chemicals, where, in addition to deadly consequences, the bodily labour involved is unreasonably severe and long-continued.

Again, there are occupations in which it may, and often does, happen that the slightest carelessness or indiscretion on the part of the worker is visited with the extreme penalty of death, as witness the case of the collier, or the steeple-jack.

These men, who carry their lives in their hands,—these slowly perishing victims of noxious trades,—surely they are tempted by wages calculated to recompense them, while courting death to gain a livelihood, for the awful risks they incur in their every-day work?

No! The cost of human life is borne by the workers themselves, and is not, I believe, taken into account in any shape or form by the employer. Nevertheless, the supply of men to fill the ranks is in excess of the demand; and one is driven to the conclusion that the price of labour is not regulated either by the severity of the work itself or by the danger to human life involved.

Is it, then, regulated by the length of time worked? It would not be altogether unreasonable to suppose that in certain trades, where the custom of working long hours obtains, a high rate of wages would be the rule. The con-

trary, however, is the case, as a glance at the conditions prevailing in the London East-end indoor trades would show.

For what, then, is a man paid? Turn back to the word at the head of this article and you have the answer, Responsibility!

The measure of the employed person's market value is in terms of his responsibility. This aspect of the case will supply a key, not only to the two or three anomalies of the labour market which have been noted, but to most others which arise. "To whom much is given, of him shall much be required."

Thus, the Irish labourer, arrived at New York, and inviting his mate in the old country to join him, spoke a truer work than he knew when he described himself as getting so many dollars a day for nothing but carrying bricks to the top of a chimney—"the man at the top does all the work." I think this old story (always, most unfairly, told with the intention of turning the laugh against Pat) puts the case in a nutshell. It is the "man at the top" who does all the work of real value,—the responsible work,—and he would receive probably double Pat's wages for doing it. To make this quite clear, let us analyse the work of the two men.

In actual physical labour Pat's work is incomparably heavier than that of the bricklayer; he risks his neck also to a vastly greater extent. We may put Pat down as being engaged in a trade combining the elements of laborious toil and continual danger to life and limb in an unusual degree. But Pat's responsibility begins and ends with the conveyance, in a perpendicular direction, of his load of bricks; accordingly he draws the ordinary wages of a day-labourer, with nothing thrown in to compensate for the risks he runs in the performance of his task.

Now take the other member of the firm, the bricklayer. With far less physical toil than falls to the lot of Pat, he enjoys a greatly superior stipend. For what? Perched upon his lofty, but secure, platform, he exercises his craft (such is the theory, at any rate) in laying, well and truly, each separate brick in its appointed place. Upon his skill depends the safety for all time of the finished structure. Pat's life, as well as his own, during the progress of the building hangs upon his skill and judgment in the construction of the progressive stages of the slender scaffolding in which the structure is enveloped.

In a word, the responsibility, for good or ill, in this matter is all his own, and it is on account of this particular item of his services, and neither for his toil nor for his risk, that his remuneration is so much in excess of poor Pat's. Over him may be a foreman, who toils not at all, neither does he exercise any manual skill; the article he has to sell is responsibility pure and simple. His wages, again, are calculated on a much more liberal scale than those of the bricklayer.

Now, bringing this doctrine of responsibility to bear upon the engineering factory, we shall see that it applies perfectly throughout, from the almost irresponsible day-labourer,—the hewer of wood and drawer of water,—up to the general manager, who has upon his hands the success or failure of the whole business,—manufacturing and commercial. The one man may be in reality underpaid, though he receive thousands per annum; his loss or defection might conceivably so affect the fortunes of the concern that scores or hundreds of workmen might lose their employment. The other, whose services command only a single pound per week, may, not impossibly, be receiving more than his actual value would warrant, and a substitute, with acquirements equal to the situation, might be obtained almost at a moment's notice.

The highest posts, and the most coveted distinctions which the world of commerce and industry has to offer, are open to those fortunate individuals who are gifted with the genius of administration or of finance. With the latter of these qualifications we are not for the moment concerned, and (with the incidental note that the exceptionally

lucky mortal born with both these ruling faculties steps forthwith into an assured inheritance of power and wealth) we may pass on to consider the position and responsibilities of the man who stands at the head of a great industrial undertaking.

The work of controlling the destinies of the concern is, in all probability, vested in a board of directors; but it not infrequently happens that the functions of this board are purely advisory, and that practically a free hand is given to a single person who plays the actual game and manipulates his human pieces according to his individual judgment.

Strange as it may seem to many, it is by no means a necessity that this man should be skilled in the practice of the trade over which he presides. His trade, in fact, is administration, and, if he be a master-craftsman in that respect, he will know how to surround himself with efficient technical and commercial experts in every branch, capable of filling in the subsidiary portions of the schemes which he has eyes to look upon only in their broad significance.

In a position like this, with all the resources of a great commercial corporation at his back, this man, with his fingers upon the pulse of commerce, may, through wise and skilful administration, steer his undertaking safely through years of depression and scarcity, while others, under a less efficient pilot, may founder and be lost. Is it too much to say that this man plays the part of an earthly Providence to the hundreds or thousands of families dependent upon the running of his factory for their daily bread?

Imagine the consequences which inevitably follow upon mistaken policy or wilful blindness long-continued on the part of the responsible head of a large manufacturing concern. The great works, with machinery silent and rusted, the grass-grown yards, the streets of deserted houses,—these are only the outward and visible signs of a bitter distress, of months of hoping against hope, of the closing of the doors, and the breaking up of the homes.

We have seen enough to realise the weight of responsibility laid upon those who take upon themselves the control of great undertakings. And commensurate with the responsibility is the magnitude of the successful administrator's well-deserved reward.

Scarcely second in importance to the duties of the general manager are those which devolve upon the engineer,—the executive head of the works. In addition to the responsibility of organising and controlling the operations of the complex machinery of a modern factory, he is called upon to decide almost at a moment's notice, amid a multitude of lesser matters, questions or problems involving the most far-reaching consequences. Take a constantly recurring instance in all businesses of this kind:—

Certain commercial considerations appear to dictate the necessity, if the firm wishes to retain the trade in some particular branch, of putting upon the market immediately an improved article, whether it be a steam-engine or a machine tool or a gun. The commercial head of the concern has just informed his colleague at the head of the manufacturing department that their goods are being passed over in favour of those made by a rival firm, to which an effective checkmate must be devised. Immediate action must be taken. What is to be done?

The engineer begins to think. Let us watch him, and, ourselves unperceived, observe the genesis of an invention. Idly, almost, at first, a few apparently aimless strokes and figures make their appearance on a sheet of blotting-paper or the back of a letter. Presently some roughly sketched detail, half-unconsciously jotted down, indicates that the inventor's brain is at work, that marvellous dual instrument of thought, whereof the one part,—the only one of which its owner is conscious,—is apparently engrossed in the most trivial objects, tracing the exact pattern of the chair-back opposite, or studying the spots of ink on the blotting-pad,—the flotsam and jetsam of the mind.

But, presently, as conjured up by some powerful spell, from an inner cham-

ber, emerges, in due order and sequence, the solution of the problem, clear, complete, unassailable. Now, the conscious brain, if I may so distinguish it, takes up its share of the work. In obedience to its commands, the trained eye and the educated hand are already hard at work, transferring rapidly into visible and permanent form the fleeting image of which the impression upon the mental retina is already becoming blurred and indistinct.

A few masterly strokes upon the paper and the thing is done. The inventor looks up, but it is with the look of a man emerging from a dream. The tension is over, the desired result is before him, the rest is but "leather and prunella;" but those few minutes of high-pressure thinking have not been accomplished without taking something out of the man. That second brain, or inner chamber, charges a heavy fee for its brief period of activity; there is a sense of mental exhaustion or weariness which shows how severe has been the strain.

In those few minutes of intensely concentrated thought it is not impossible that the inventor may have materially affected the future prosperity of the concern for good or for ill. This is not a business for blunderers to engage in. But a man who, at a moment's notice, can strip a problem of its negligible details,—who can grasp the crux of the situation and focus upon it, in a few moments, all the insight gained by the experience and knowledge and training of half a lifetime,—that is the man whose work, carried on successfully day by day, under pressure of a heavy responsibility, will always carry with it the certainty of an adequate reward.

The moral to be drawn from all this is, of course, to put it in homely language, that a young man who desires to get on must make use of something beyond his pair of strong and skilful hands. Hand-workers there are in plenty, and always will be. Here and there amongst their number may be found one who, while as zealous and able as the best of them in his handicraft, is on the alert to secure a chance of emerging from the ranks.

It is to such as he that my words are addressed, and my advice to such (if I may offer it) is:—Fit yourself for a post of responsibility as speedily as possible! Your determination to do this puts you at once upon a path diverging considerably from that pursued by your shopmates who are content to tread the beaten track. You can no longer subscribe to the doctrine which compels the leaders of trades-union combinations to discourage individual effort and seek to spread the work to be done over as many hands as possible. Their aim is to keep their members off the funds of the union, very naturally; and if the quantity of work to be done were unlimited, and the question of cost in doing it consequently negligible, their policy would be less short-sighted than it appears to be at present.

But, unfortunately, this is very far from being the case; and if you are capable of thinking for yourself, you are quite justified in asserting your individual right to exert all your inherent and acquired faculties in the effort to obtain a better price for your services. Your question must be:—How can I increase my market value?

I invite you to consider yourself, your work, and all that appertains to it from an entirely new point of view. I think I am not mistaken in saying that hitherto you have always regarded your work as something which has to be done as a means of getting a living. This aspect of it, involving, as it does, the questions of price, time expended, number of hours to be worked per day, and so on, though perfectly legitimate in itself, is not likely ever to lead to any advancement in your position and prospects worthy of serious consideration. To fit yourself for a responsible position you must take a broader view than this; and, paradoxical as it may seem, you can advance your own interests only by studying those of others.

Your principle must be, that after having once made your bargain with your employers,—and make the best

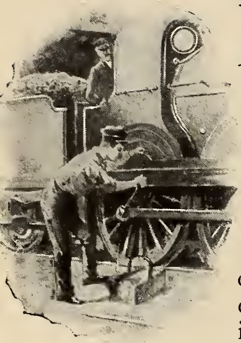
terms you can while you are about it,—your whole intelligence and energies during business hours must be devoted to the interests of the concern which is finding you in bread-and-butter. Your work will assume a new interest for you, and the time will no longer hang heavily on your hands. There are a hundred ways in which you can let your foreman or your employer see that your desire is to serve his interests, and the temporary sacrifice of your own in such a cause will pay you well in the long run.

But all this is only one part, and that by no means the most difficult part, of what you must do to prepare yourself or promotion. You will have to give up some of your hard-earned leisure, and devote not a little of your time to beginning,—I use the term advisedly,—your education as an engineer. The old-fashioned "practical man," who is, though he does not know it, actually proud of his ignorance,—and truly he has much to be proud of,—finds no place, nowadays, upon the staff of an engineering factory; he is fitted to act only under direction. Knowledge is power, and you must know more than those around you if you aspire to be a leader.

Use freely what you have learnt! Give your employer of the best you have, and, depend upon it, you will, at some time, find a very agreeable change in your duties, accompanied by an equally gratifying addition to your salary. Then, with your feet upon the first step of the ladder, the true meaning of the word which forms the text of my article will open up for you.

BRITISH FOUR-CYLINDER LOCOMOTIVES

By George Frederick Bird



LOCOMOTIVE practice in Great Britain during the past two years has been distinguished by an important development, which, judging by the results already achieved, bids fair to have "come to stay." This concerns the number of cylinders employed. It is, of course, quite within the intimate knowledge of the readers of these pages that for some years past four-cylinder locomotives have been extensively built in the United States, this number of cylinders being an important feature of the system of compounding introduced by Mr. Vauclain, of the Baldwin Locomotive Works. On the Continent of Europe, moreover, engines with four cylinders have also, from time to time, been built; and there have not been wanting instances, common to all countries, where that number of cylinders has been employed in locomotives of special construction, such as the Fairlie and other engines built on double bogies or trucks, where a pair of cylinders has been utilised to drive each of two separate sets of driving wheels.

In Great Britain, however, the standard practice has proceeded on strictly conservative lines in this respect until quite recently; and with but few exceptions, which may, by their comparative rarity, be said to have accentuated the prevailing rule, the number of cylinders per engine has been limited to two, driving the same axle by means of cranks set at an angle of 90°. And on this account, by reason of this consistent conservatism of custom, the recent unmistakable departure of three well-known British locomotive engineers from the beaten track of established practice is more noteworthy than would have been the case in a country more conspicuous for its daring in the attempt to form new ideals.

Before dealing in detail with these new departures, however, it may be of interest, and not altogether out of place, to glance briefly at previous movements in the same direction. The first four-cylinder locomotive of which there is any record was the *Stockton*, No. 5 in the books of the Stockton and Darlington Railway Company, which was built for that line in 1826 by Messrs. Wilson & Co., of Newcastle-on-Tyne. This engine had two pairs of independent driving wheels, each 4 feet in diameter, and each pair driven by two vertical cylinders, 6 inches in diameter, with a stroke of 18 inches.

Each pair of cylinders worked cranks on the outside of the wheels, so set that one piston was at the end of its stroke while the other was at midstroke; and it is worth noting that the *Stockton* appears to have been the first engine that was constructed with two cranks, so set, acting directly upon one pair of wheels. Previous engines having two cylinders had, indeed, been built; but each cylinder had driven only one pair of wheels directly, the necessary correspondence of the two in relation to the avoidance of dead centres being arrived at clumsily enough by means of spur wheels, endless chains or coupling-rods.

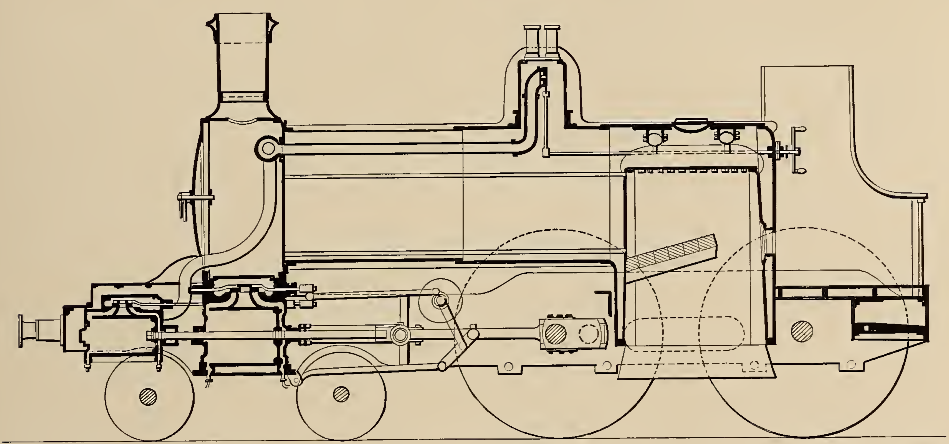
Despite the ingenuity displayed in its design, however, the *Stockton* was not a success, and the occasion of a trifling collision served as an excuse to withdraw it from service. Subsequently, in 1827, the railway company's locomotive foreman, T. Hackworth, took in hand the task of rebuilding the engine, and

converted it into a two-cylinder six-coupled engine, which, with the new name of *Royal George*, began work in October of that year, and, in course of time, achieved some fame.

Nearly twenty years later, in 1846, Stephenson and Howe patented an arrangement of three cylinders, one being placed in a central position under the smoke box, and the others in such a position as to drive crank pins on the outside of the driving wheels. These outside cylinders both made the forward or backward stroke of the piston simultaneously, and the inside crank was set at right angles to the outer crank-pins, as in ordinary two-cylinder engines. The idea which prompted this arrangement was to obtain "greater natural stability than was arrived at in other locomotives," this end being attained presumably by the balancing of the reciprocating masses acting out of the centre line of the engine, which latter would tend to produce a more or less pronounced sinuous motion of the locomotive across the rails.

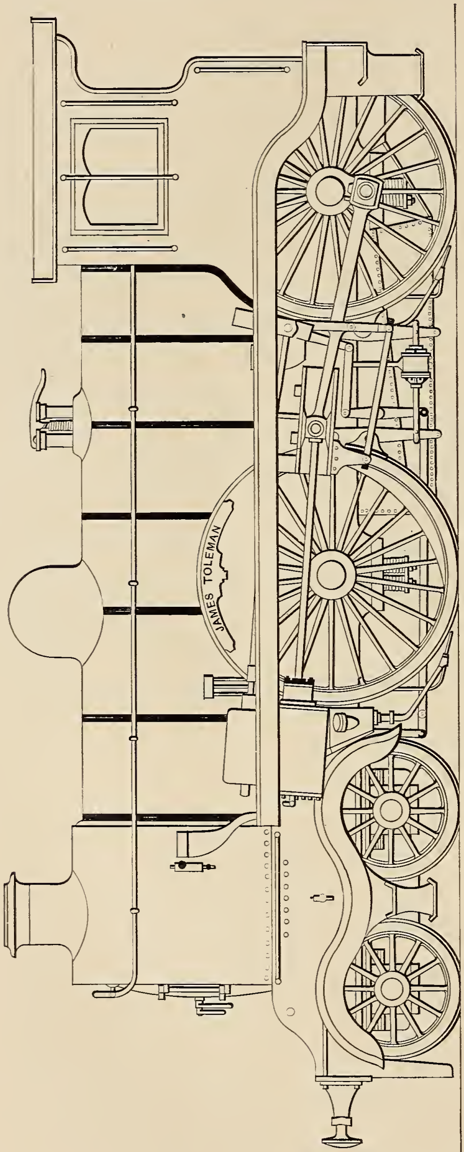
An engine built to this design, having two outside cylinders, 10½ inches in diameter, with 22 inches stroke, and one inside cylinder, 16⅜ inches in diameter, with a stroke of 18 inches, all three driving a single pair of driving wheels, 6 feet 8 inches in diameter, the engine being supported altogether on six wheels and weighing 27 tons in working order, was built for the York, Newcastle and Berwick Railway, and appears to have given a moderate degree of satisfaction. But, apparently, it showed no pre-eminent advantages sufficient to outweigh its greater original cost and expense of upkeep, and the design was not perpetuated.

Some years later still, a four-cylinder engine was designed by an Englishman, but not for a British railway. This was the *Duplex*, a six-wheeled single-driving engine, built by Mr. John Haswell, of the Austrian State Railway Works at Vienna, which was exhibited in London at the International Exhibition in 1862. It was specially designed to secure steadiness at high speeds, and with this end in view it was provided with two cylinders for each driving wheel, placed outside the frames and so arranged that each pair of pistons worked crank-pins diametrically opposite to each other, thus securing a perfect balance of the reciprocating parts. One slide valve worked each pair of pistons by an ingenious system of crossing the steam-passages. The cylinders were 10⅞ inches in diameter, with a stroke of 24⅞ inches, and they drove a pair of wheels, 6 feet 9 inches in diameter, immediately in front of the firebox, with the four carrying wheels of the engine in advance of them.



NISBET'S FOUR-CYLINDER COMPOUND LOCOMOTIVE

The engine had a total heating surface of 1344 square feet, and weighed 31 tons 14 cwt. in working order, of which 12 tons 6 cwt. were available for adhesion, and a great proportion of the remaining load was taken by the leading wheels, with a comparatively light weight on the intermediate pair. In actual work, this locomotive seems to have proved satisfactory, but evidently it possessed no advantages sufficiently marked to warrant a continuance of the type, and it probably showed no very great superiority as compared with its eleven sister engines, which, while of the same general design, were provided with only two cylinders apiece.



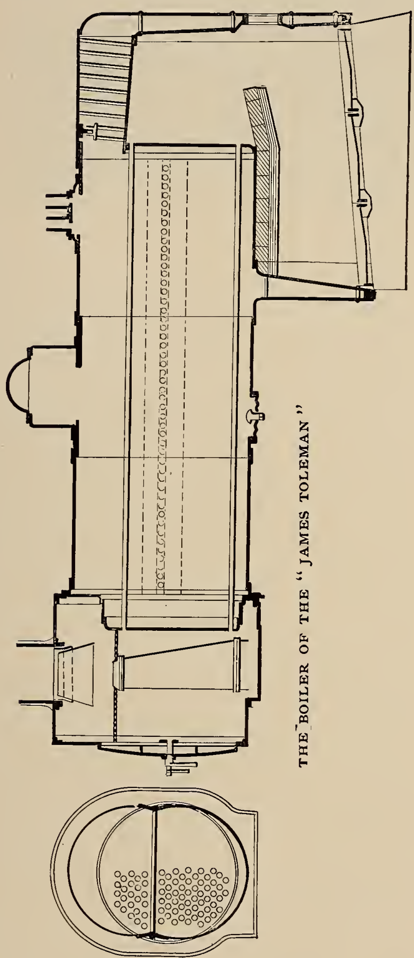
WINBY'S ENGINE THE "JAMES TOLEMAN."

Mr. F. W. Webb was the next British engineer who sought to derive increased advantages from the adoption of more than two cylinders, and in 1878 he made his first experiments to that end, holding back from the scrap heap for the purpose an old single-driving engine, built by Trevithick about thirty years previously. The result of extended trials of this engine, converted into a compound on M. Mallet's system, was the designing, in 1881, of the first of his well-known class of three-cylinder compounds, of which a large number have since been built for express passenger, local and goods traffic. These have given complete satisfaction to their designer, and deal with the fastest and heaviest trains upon the London and North Western road.

Reverting strictly to four-cylinder engines, we find that, shortly after the London and North Western Company had decided definitely for the compound principle, Mr. W. Dean, of the Great Western Railway, built two four-cylinder compound locomotives for that line. These received Nos. 7 and 8 in the books of the company, and were designed for the 4-foot 8½-inch and 7-foot gauges, respectively, with their cylinders arranged on the tandem principle, driving four-coupled wheels of 7 feet diameter. Very little information has been made public with regard to these experimental engines, but we are free to infer, from the fact that they have since been converted into simple engines of the eight-wheel, four-coupled type, that Mr. Dean found no advantages to accrue from an extended trial of the four-cylinder compound system.

Still another tandem four-cylinder compound was subjected to trial, this

time on the North British Railway. The engine in question was noteworthy on account of its history, apart from other considerations, since it had gone through at least one experience fortunately rare in the life-history of locomotives. It was originally built in 1871 at the North British Railway Company's



THE BOILER OF THE "JAMES TOLEMAN"

works at Cowlairs, and was delivered in steam on the line as No. 224, a sister engine, built at the same time, being No. 264. These engines were of the eight-wheeled type, having four coupled wheels, 6 feet 6 inches in diameter, and a leading four-wheeled bogie or truck, the wheels of which were spokeless and 2 feet 9 inches in diameter. With inside cylinders, 17 inches by 24 inches, a total of only 981 square feet of heating surface, and a weight in working order of 36 tons 1 cwt., they were by no means exceptional locomotives as regards either design or power.

But No. 224 happened to be put on duty on Sunday night, December 28, 1879, and was at the head of the ill-fated train which went down with the Tay Bridge on that memorable occasion. For many months afterwards the engine lay at the bottom of the river, apparently lost beyond recall, but ultimately it was fished for and lifted from its watery bed, and, strange to tell, was for all practical purposes little damaged. Landed at Tayport, it travelled on its own wheels back to its birthplace and was speedily put into working order once more, and performed useful duty.

In 1885-6, however, Mr. Holmes, the locomotive engineer of the company, in casting about for an engine on which to try experiments, happened on No. 224, and another visit to Cowlairs enabled it to make still another appearance, this time as a four-cylinder tandem compound, arranged on Nisbet's patent. The skeleton elevation on page 143 shows the leading features of the engine as then converted. Under the smoke box, in the usual position, were arranged a pair of low-pressure cylinders having a diameter of 20 inches, while forward of them, immediately above the leading bogie wheels, were a pair of high-pressure cylinders, 13 inches in diameter. One piston rod was common to each pair of high and low-pressure cylinders on the right and left-hand, respectively, with a common stroke of 24 inches. As can be seen from the drawing, Joy's valve gear was employed, and it was so arranged that the high or low-pressure valves could be worked expansively with complete independence, to suit particular conditions. Another feature was the provision for allowing the high-pressure cylinders to exhaust directly into the casings of the low-pressure cylinders, without the employment of an intermediate receiver.

For some time, the engine worked

MANSON'S FOUR-CYLINDER LOCOMOTIVE ON THE GLASGOW AND SOUTH WESTERN RAILWAY

regular trains on the North British Railway, in this form, and was said to show good results in economy of fuel and general efficiency. However, despite this encouraging report, she can scarcely have proved fully successful, for once more the resources of the Cowlairs shops were called into play, this time to convert her back again into a "simple" engine with two high-pressure cylinders only. And here the historical value of No. 224 seems to end, for the present.

An account of British four-cylinder locomotives would certainly not be complete did it include no reference to that "splendid failure," Mr. F. C. Winby's locomotive, the *James Toleman*, which attracted considerable attention at the Columbian Exposition at Chicago, in 1893. Mr. Winby, who, by the way, served an apprenticeship in the Crewe shops of the London and North Western Railway and subsequently became a member of a well-known British firm of railway contractors, seems to have been actuated originally by a desire to design a locomotive of exceptional size and power, but otherwise differing to no great extent from existing British practice, his original data apparently being a pair of cylinders 22 inches in diameter, with a stroke of 28 inches. He found, however, that to procure the necessary supply of grate area to utilise effectively so large a tractive force, it would be necessary to separate the two driving axles of his original engine so widely as to prolong unduly the coupling rods, the grate area in engines of standard pattern being capable of extension only in the direction of length.

Under these conditions, he had no option, apparently, except to abandon his original conception, and to substitute for a single pair of cylinders driving two pairs of driving wheels coupled together by side rods, two pairs of cylinders each set of which would drive an independent pair of driving wheels. The resulting design was that shown on page 144, which represents the *James Toleman* as it was originally built and as it appeared during the months it was on view at the Chicago Exposition. It was an eight-wheeled engine, having a four-wheeled bogie or truck at the leading end, and two pairs of independent driving wheels, each 7 feet 6 inches in diameter, spaced with their axle centres at a distance of 11 feet 4½ inches apart.

The first pair of driving wheels was driven by a couple of inside cylinders placed in the ordinary position under the smoke box, with a diameter of 17 inches and a stroke of 22 inches. These were fitted with Stephenson link motion of the ordinary pattern. The second pair of driving wheels was driven by two outside cylinders having a diameter of 16½ inches and a stroke of 24 inches, provided with Joy's valve gear, and while one reversing lever sufficed

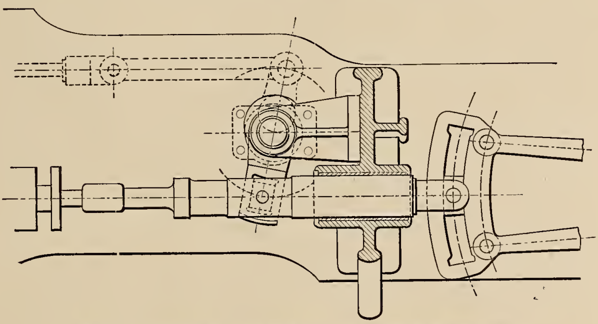
to control each set of motions, the two sets of cylinders and wheels were capable of perfectly independent action.

Up to this point, the engine seems to contain the promise of exceptional efficiency, possessing, as it did, a flexible wheelbase, large driving wheels and ample cylinder capacity. But, unfortunately, the boiler is the true measure of a locomotive's power, and it was in this vital particular that the designer committed his fatal error. The boiler contained two marked departures from recognised practice, both of which undoubtedly contributed to its ultimate lack of success. A reference to the sectional views on page 145 shows a boiler barrel of comparatively short, and a firebox of correspondingly long, dimensions. As a matter of fact, the boiler barrel was only 9 feet 2¼ inches in length, and the firebox shell 8 feet 11½ inches in length, the length available for grate area inside the copper plates of the firebox proper being 8 feet 3¾ inches.

But an examination o the sectional view shows that the length of boiler barrel afforded no measure of the distance between the tube plates, which were no less than 14 feet 9¼ inches apart. To secure this extreme length, the water space of the boiler was recessed into the smoke box to the extent of 12¾ inches, and similarly encroached on the firebox space to the still more important degree of nearly 4 feet, reckoning from the position of the firebox tubeplate in normal designs. To this extent, the heating surface of the firebox,—one square foot of which equals in efficiency for steam production many square feet of tube surface,—was unduly restricted in order to provide greater surface in the tubes, and the firebox as thus planned was, moreover, of a shape not particularly suited to secure the utmost efficiency.

So far for one feature to which adverse criticism may fittingly be applied but another still remains. In order to secure a large boiler barrel, while restricted as to its transverse diameter by the distance apart of the driving wheels on their axles, Mr. Winby abandoned the ordinary circular section and substituted for it a section composed of two portions of circles, each with an outside radius of 2 feet 1 inch, and with their centres 1 foot 5 inches apart in a vertical direction.

The boiler barrel resulting from this method had an extreme outside vertical diameter of 5 feet 7 inches and an extreme cross diameter of 4 feet 2 inches, with a longitudinal indentation on each side at the centre line caused by the reentering angles of the two portions of circles of which it was composed. To compensate for the obvious weakness of this section, strong, curved covering strips were placed from end to end of the barrel along these indentations, with three alternated rows of rivets on each side of the junction of the two plates, and, furthermore, a single row of horizontal cross stays was also employed at this point to bind both covering strips and boiler plates firmly in position. No fewer than 235 tubes, 2 inches in diameter, were packed within this boiler barrel, some being above, but the greater number below, the line of horizontal cross stays.



DETAILS OF ROCKING SHAFT OF MANSON'S ENGINE

The total heating surface of this immense boiler was 2000 square feet, of which the firebox had 182.6, and the tubes, 1817.4 square feet; and the grate area was 28 square feet. Needless to

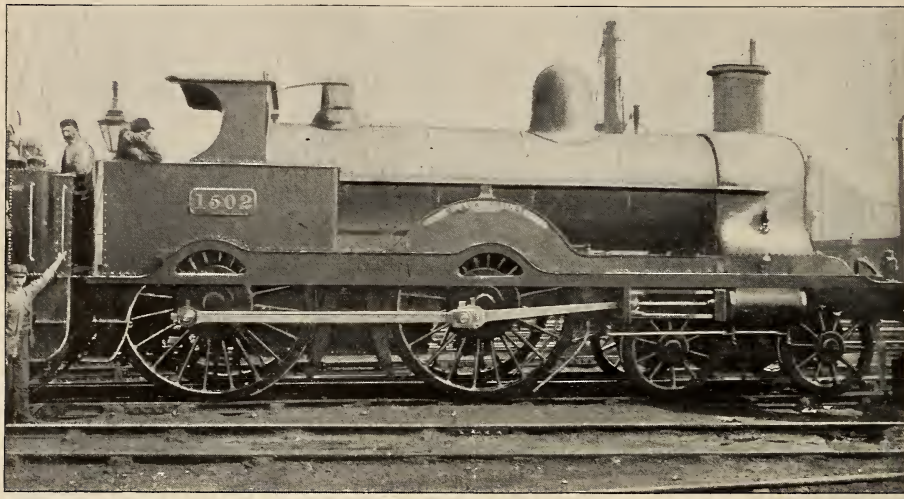


PHOTO BY F. MOORE, LONDON.

WEBB'S FOUR-CYLINDER COMPOUND DOUBLE-STACK LOCOMOTIVE "BLACK PRINCE," ON THE LONDON AND NORTH WESTERN RAILWAY

say, this huge engine was proportionately heavy, weighing in all 60 tons, of which 35 tons were available for adhesion, and it was to be provided with a double bogie tender, which, when loaded with 7000 gallons of water and 10 tons of coal, would weigh about 65 tons.

Before going to Chicago, the *James Toleman* had been given no opportunity of showing its capability for work, but at the close of the Exposition it was put upon the track of the Chicago, Milwaukee and St. Paul Railroad, and required to do its share of ordinary traffic. The result might almost have been foreseen. Though built of the finest materials and with the utmost skill by one of the leading firms in the United Kingdom, Messrs. R. & W. Hawthorn Leslie & Co., Limited, of Newcastle-on-Tyne, neither excellence of materials nor quality of workmanship could avail to conquer the inherent defects of design. As might have been expected, the boiler was the chief, if not the only, offender; the side stays leaked, and there was a general tendency to fail to produce steam. The engine was finally side-tracked at the Milwaukee shops, and, for all the writer knows to the contrary, she may be seen there to this day.

So much for the past and its failures! It is now time to deal with the present and what bid fair, judging by present results, to be its successes. In any event, the almost simultaneous appearance on three leading railways in the United Kingdom of as many different kinds of four-cylinder locomotives, designed, all of them, by practical men of experience and put to work at once on traffic noted the wide world over for its excellent conduct and exigent qualities, is of itself a sufficiently noteworthy sign of the times.

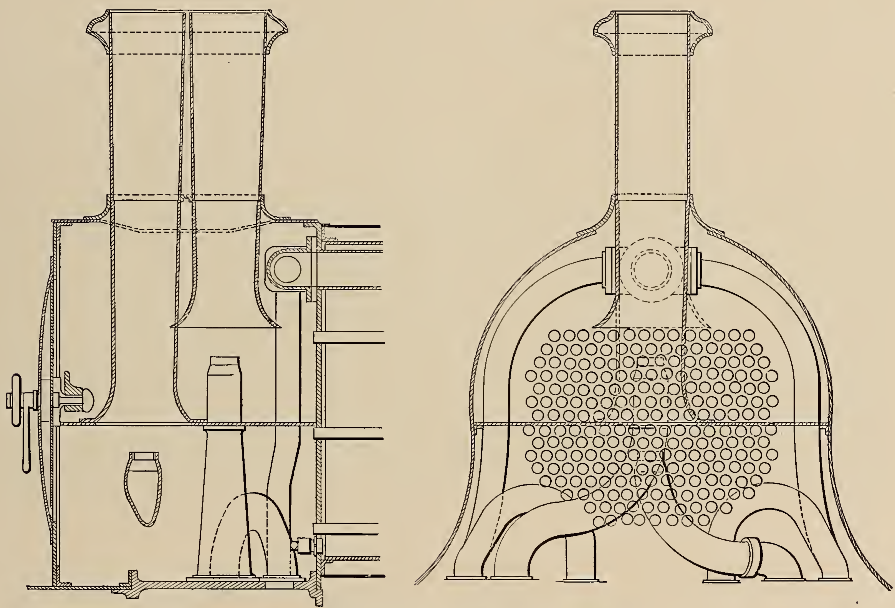
Though all these new engines have made their first appearance within considerably less than a twelvemonth, —a fact that will cause difficulties to the historian of the future who seeks to apportion credit to the designer who was earliest in the field,—the palm due to a first appearance must be awarded to No. 11, of the Glasgow and South Western Railway, of Scotland, designed by Mr. James Manson, locomotive engineer to the line, and built at the company's own works at Kilmarnock.

This engine, to which brief reference has already been made in the May number of this magazine, was set to work on April 13, 1897, and was at once put into regular service, working ordinary express trains between Carlisle and Glas-

gow, its mileage up to the end of the year 1897 being 24,575 miles. In general design, as can be seen by the illustration which is reprinted in this issue, No. 11 is practically identical with the standard eight-wheel bogie engine introduced on the railway by Mr. Manson in 1892. That is to say, it has four coupled driving wheels, 6 feet 9½ inches in diameter, and bogie wheels, 3 feet 7½ inches in diameter, a boiler of standard dimensions, containing a total heating surface of 1205 square feet, and a fire grate area of 18 square feet, and other leading dimensions of standard figures.

However, instead of having the two usual inside cylinders of 18¼ inches diameter and 26 inches stroke, it has, same power by the use of two cylinders only would have presented no very obvious mechanical difficulties, this subdivision affords a perfect balance of the reciprocating masses. Nor is there any undue complication or multiplicity of parts in the motion. One pair of eccentrics and link gearing suffices for the two cylinders on one side of the centre line of the engine, the valves for the inside cylinders being driven direct, as in the case of ordinary inside cylinder engines, while those outside are connected with the same motion by means of a rocking shaft.

The valves of the outside cylinders are placed on the top and are of a balanced pattern fitted with a release ring



SMOKE BOX DETAILS OF THE "BLACK PRINCE"

in their place, two cylinders, 14½ inches in diameter, and of 26 inches stroke, placed between the frames below the smoke box; and, furthermore, two additional cylinders, 12½ inches in diameter and of 24 inches stroke, placed outside and driving crank-pins on the outside of the driving wheels. These four cylinders are equal in capacity to a pair having a diameter of 19 inches and 26 inches stroke, and while to produce the or piston, the whole arrangement of valves, rocking shaft and motion being one that Mr. Manson originally designed some years ago. The accompanying sketch shows the leading features of the motion relating to one pair of cylinders. Apparently, the extra weight resulting from the use of four cylinders and the necessary gear amounts to about 3½ tons, the engine in working order scaling 48 tons 10 cwt., as compared with

45 tons 1 cwt. in the standard two-cylinder locomotives of the same line. The boiler pressure carried by No. 11 is 165 pounds to the square inch.

Mr. F. W. Webb, the well-known locomotive engineer of the London and North Western Railway, produced in rapid succession two four-cylinder engines of striking design, one of which, No. 1501, the *Iron Duke* (since re-christened *Diamond Jubilee*), has four high-pressure cylinders arranged abreast, two inside and two outside the frames, and all of the same size, 15 inches in diameter, with a stroke of 24 inches. The other engine, No. 1502, *Black Prince*, differs from the former in being a compound, having two high-pressure cylinders, each 15 inches in diameter, with a stroke of 24 inches, outside the frames, and two low-pressure cylinders, each originally 19½ inches in diameter, with a stroke of 24 inches, inside the frames.

In all other respects the two engines are of practically the same dimensions, and in design present unusual features on the London and North Western Railway, being the first express passenger engines so far built for that road to which a leading bogie, or truck, has been supplied. As can be seen from the illustration of the *Black Prince* on page 148, the engines are of the eight-wheel type, having a leading bogie, as already mentioned, and four-coupled driving wheels, 7 feet in diameter. The boilers are of standard dimensions adopted some years ago for Mr. Webb's large six-wheeled compound engines, containing 1400 square feet of heating surface and a grate area of 20.5 square feet, with a boiler pressure of 175 pounds to the square inch. At the leading end, however, a distinct innovation is introduced by the employment of a smoke box of unusual pattern surmounted by a double chimney. The sectional views on page 149 clearly explain how this smoke box is arranged.

Roughly speaking, the orifices of the boiler tubes at this end of the boiler are divided into two groups by means of a complete diaphragm extending horizontally over the whole length and width of the smoke box. One opening only is made in this diaphragm so far as the lower part of the smoke box is concerned, and this consists of an extension downwards of the chimney nearest the leading end of the engine, into which the exhaust from the left hand pair of cylinders discharges. The blast pipe of the right-hand pair of cylinders, on the other hand, is continued through the diaphragm and exhausts into a petticoat pipe at the base of the second chimney. Thus, the left-hand exhaust induces draught through the lower half of the tubes, and the right-hand exhaust performs the same function with regard to the upper half. The double chimney is not particularly noticeable from the outside, as a filling piece is inserted on each side, and a neat cap is used to cover it over.

After being at work for some time so fitted, the two engines were taken back to the shops, and the double chimney, diaphragm and separate blast pipes were removed in each case, and a single chimney of ordinary pattern was substituted. Mr. Webb has been good enough to relate to the writer the result of this retrograde experiment. He found that the non-compound engine, so altered, did not steam nearly so well as before, and burnt more fuel, while with the compound engine, the alteration made no difference.

The conclusion he arrived at, therefore, was that with the non-compound engine the divided smoke box and double chimney is a decided advantage, as the arrangement allows of a greater length of time between the exhausts, and therefore gives the fuel more time to impart its heat to the water before it passes through the tubes; in the compound engine, which has only half the number of exhausts, the same advantage is not experienced. It is probable, therefore, that the double chimney, diaphragm and divided exhaust will be replaced in the *Diamond Jubilee*. Mr. Webb has also informed the writer that it is his intention to increase the diameter of the low-pressure cylinders in the *Black Prince* to 20½ inches, with the idea of getting still better work out of

the engine than at present. Joy's valve gear is employed on both engines, and by an arrangement very similar in principle to that used on the Glasgow and South Western engine, but differing essentially in design, one valve motion suffices for each pair of cylinders.

To a certain extent both engines are of the balanced order, having the inside crank on one side of the centre line opposite to the outside crank on the same side, and to that extent they do not require the usual counterweight in the rims of the driving wheels. However, to secure as perfect a balance as possible, the crank shaft, which is of the "built-up" pattern, is supplied without a stop, and returns from Euston the same night at 11.50 P. M. with the sleeping-saloon express, which runs through to Crewe, 158 miles, without a stop, in 3 hours and 5 minutes.

Since first getting to work in June of last year, No. 1501 has run a distance of 33,517 miles, with an average coal consumption of 40.3 pounds per mile. The compound engine, No. 1502, made her first trip on August 2 of last year, and up to February 28 of the present year had covered a total of 23,503 miles on a consumption of 38.1 pounds per mile. The compound is thus the cheaper of the two by 2.2 pounds per mile. No, 1502 weighs, in working order, 53 tons.

PHOTO BY F. MOORE, LONDON

DRUMMOND'S FOUR-CYLINDER LOCOMOTIVE ON THE LONDON AND SOUTH WESTERN RAILWAY

with large projecting cheeks opposite to the crank throws, while for the outside cranks a counterbalance is provided by enlarging the wheel centres to an unusual extent and adjusting counterweights in them. With the exception of a few days' holiday from time to time for painting and alterations to the smoke box, these two engines have been in regular service together, running on alternate days the heavy express corridor dining-car train which leaves Crewe at about 5 P. M., and goes through to Willesden, a distance of 152½ miles while the non-compound is somewhat lighter.

The remaining four-cylinder engine on our list is No. 720, of the London and South Western Railway, and is, the writer understands, the first passenger express locomotive actually designed by Mr. Dugald Drummond since he took over charge of the locomotive department of that line some time ago. The engine, which is shown on this page, is of exceptional dimensions. Unfortunately, however, it is still in what is known as the "experimental" stage,

so that its originator is naturally loth to be premature in giving details of its work. In general arrangement it claims something of kinship with Mr. Winby's unfortunate *James Toleman*, inasmuch as it has two pairs of independent driving wheels, each with its own supply of cylinder power. The driving wheels are all 6 feet 7 inches in diameter, and the two pairs are spaced with their centres 11 feet apart, thus providing plenty of room for an ample firebox, while the length of the boiler barrel is also sufficiently extended by the generous wheel base allowed forward of the driving wheels. But not only is the firebox of ample dimensions; it is further provided with a number of transverse water tubes in the upper part, which bring its heating surface up to the amazing total of 394 square feet. The total heating surface of firebox and tubes is 1701 square feet, and the grate area is 27.4 square feet.

All four cylinders were originally 16½ inches in diameter, with a stroke of 26 inches; they have since, however, been lined down to 15 inches in diameter, and are, even now, equal to one pair having a diameter well over 21 inches. To utilise this great tractive force, a weight of 37 tons 14 cwt. is available for adhesion out of a total of 54 tons 11 cwt. As in the Winby engine, the inside cylinders are fitted with valve gear of the Stephenson type, while the outside cylinders are worked by Joy's valve gear; one reversing gear suffices for all four cylinders, and is moved by a small lever with the utmost ease. Apart from the unusual design of the engine itself, attention may be drawn to the tender, which presents features comparatively novel in British practice. It is of large size, holding 4300 gallons of water, and is carried on two four-wheeled bogies with the frames inside.

It is said that No. 720 was designed primarily to run trains through from Waterloo to Exeter, a distance of 171½ miles, without a stop; but this statement, so far, lacks authority. In ordinary express work the engine is certainly capable of dealing with loads consisting of no fewer than twenty or twenty-two double-bogie coaches over a road by no means the easiest in the world.

It should be remembered by those who may seek to compare these relatively small engines with those immense machines familiar in the United States, that limitations fetter British designers which are unknown on the other side of the water. There are limitations resulting from financial considerations, from conditions of working traffic, from structural conditions unconnected with the locomotive department, and from many other causes, all of which tend to restrict the hand of the British locomotive engineer. Yet despite these limitations, or perhaps on account of them, it has been possible to build engines that for economy, power for weight, and general efficiency, may be held up for comparison with any others not so produced without any occasion for anxiety as to the result.

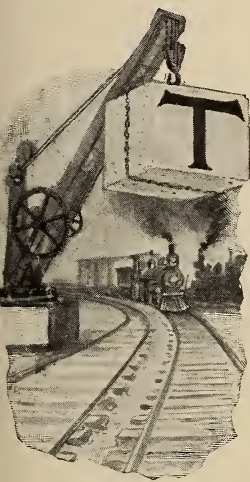
Since this article was first written, some time has necessarily elapsed, with the inevitable consequence that some few points call for slight amendment. For example, Mr. F. W. Webb, of the London and North-Western Railway has converted Engine No. 1501 (*Diamond Jubilee*) into a compound locomotive of practically the same type and dimensions as its sister engine, No. 1502 (*Black Prince*), but with the low-pressure cylinders 20½-in. in diameter. The writer understands that Mr. Webb is so far satisfied with the experimental working of these two four-cylinder compounds, which, though they are not yet in "regular" service, have been working some of the fastest and heaviest trains on the L. and N. W. road, that he contemplates building no fewer than eighteen more engines of the same type at an early date.

It is probable, in view of the interesting trials referred to in the body of the article, that none of this class will be fitted with the double chimney and divided smoke-box, since no material advantage seems to accrue from the adoption of this device in the case of the compound engine. Up to the time of

writing, Mr. Drummond's engine, No. 720, on the London and South Western Railway, has not been put into regular service, and, according to reports, it has not, as yet, given evidence of being superior in any marked degree to the ordinary two-cylinder locomotives on that road. In that case, the type is scarcely likely to be perpetuated. Mr. Manson's four-cylinder engine on the Glasgow and South Western Railway is apparently in full work, but the writer is still without particulars as to whether it shows sufficient superiority over its sister engines with the normal number of cylinders to pay for the increased first cost and greater expense of upkeep.

HENRY ROBINSON TOWNE

A Biographical Sketch



TO create, develop and successfully conduct a great and complex manufacturing industry which, in its special line, leads the progress of the world and sets the standards of utility, excellence and beauty, will be held by many to confer a higher title to greatness in engineering than identification with showy achievements which command a larger measure of public attention and invite popular applause. There has never been a time since history began, when any one of many men, under favouring conditions of opportunity and financial support, could not have linked his name with a work entitled to be classed with the seven world-wonders.

No engineering feat within the possibilities of human achievement could now be proposed, which any one of thousands of living men could not carry to successful completion. It is probable, however, that not one in a thousand, and perhaps not more than one in ten thousand, of those who are capable and qualified engineers, could conduct a great industrial development from inception to finish, organise its intricate productive and distributive systems, and keep it for a quarter of a century the leading establishment of its kind in the world. To do this requires a rare combination of the best qualities of the engineer, the merchant and the man of affairs; a still more rare capacity for infinite detail, which finds nothing too small for critical attention, and a patience and persistency of concentration which few men of genius and imagination possess. In these respects Mr. Henry R. Towne may properly be recognised as one of the greatest manufacturing engineers of the United States.

The subject of this sketch was born in Philadelphia in 1844, and had the advantage of an inheritance, through both branches of his ancestry, of the best English characteristics. His father and grandfather were successful men of affairs, with a strong mechanical bent, prominently identified with the successful industries of their day. His father, Mr. John Henry Towne, was a partner of I. P. Morris, Towne & Co., owning and operating the Port Richmond Iron Works. Henry R. Towne's youthful environment was well calculated to inculcate independence of thought and the courage of conviction. The intimate associations of his childhood and youth with Rev. William Henry Furness, D. D., of Philadelphia, a man of the highest intellectuality and a leader of the anti-slavery sentiment at a time when such leadership demanded great courage and devotion to principle, had

much to do with developing his natural characteristics and inherited traits.

After completing an academic course, he entered the University of Pennsylvania, and remained there through the college year 1861-1862. The outbreak of the American Civil War had the natural effect of unsettling the boy, who wanted to enter the army; but, parental opposition forbidding, he insisted upon getting to work, and was taken into the drawing room of the Port Richmond Iron Works, where he remained nearly two years at the drawing board. Having shown fitness for more responsible employment, he was, in 1863, put in charge of the Government work in the shops connected with repairs of the gunboat *Massachusetts*.

The Port Richmond Iron Works had meanwhile taken a contract to furnish the engines for the monitor *Monadnock*, and in 1864 Henry R. Towne, then only about 20 years old, was sent to assemble and erect them in the ships at the Charlestown, Mass., Navy Yard. This work was done so well that he was subsequently sent to the Portsmouth, N. H., Navy Yard, in sole charge of erecting and testing the machinery of the monitor *Agamenticus* (now the *Terror*), and later of the cruiser *Pushmataha*, at the Philadelphia Navy Yard. At the age of 21 he was put in general charge of the shops of the Port Richmond Iron Works as acting superintendent. Boys developed rapidly during the great national upheaval which followed secession, and those equal to great responsibilities found the opportunity to show what was in them.

When the strain was relieved by the restoration of peace, Mr. Towne realised the need of exact knowledge in many lines of study which the war had interrupted. He became a close and industrious student under the guidance and instruction of the late Robert Briggs, and accompanied him on an engineering tour of Great Britain, Belgium and France. Before returning, he took a special course in physics at the Sorbonne, in Paris. During this time his father had disposed of his manufacturing interests and retired from business. After returning to the United States the young man spent a year in further study with Robert Briggs, and in experimental work with him. During this association he gained a reputation by experiments with leather belting, the results of which were accepted as standard for twenty years. For further education in the designing and use of special machinery, Mr. Towne entered the shop of William Sellers & Co., of Philadelphia, devoted to the production of Giffard injectors, where he had a most valuable experience.

In the summer of 1868 a mutual friend introduced Mr. Towne to Linus Yale, Jr., a talented and ingenious inventor of locks, whose business, chiefly in bank locks, then employed about 30 men. Foreseeing great possibilities in the then recent invention by Mr. Yale of the lock with small flat key, now universally known as the "Yale lock," Mr. Towne proposed a partnership in which he should undertake the manufacturing management, and which resulted, in October, 1868, in the organisation at Stamford, Conn., of what is now the Yale & Towne Manufacturing Company. The association thus formed lasted but three months, being terminated by the premature death of Mr. Yale, in December, 1868. Since then Mr. Towne, as president, has controlled and directed the enterprise thus begun.

Mr. Yale's legacy to the new concern was one of brilliant ideas, which have since revolutionised American practice in lock-designing, but which could be made commercially valuable only if reduced to practice by just such work as Mr. Towne had undertaken to perform. This work occupied the succeeding ten years, and forms the basis on which has been reared a great industry, which is still in process of vigorous development. Starting with Mr. Yale's radical departure from previous types of lock construction, Mr. Towne's work has greatly amplified these original features and has embodied with them equally radical departures in design and workmanship, and especially in methods of production which have become the accepted standards of the trade.

In the brief space at the writer's command it would be impossible to give even an idea of the variety and perfection of the special machinery employed at Stamford in the production of locks, or of the steps of growth from small beginnings in 1869, when Mr. Towne became president of the Yale & Towne Manufacturing Company, to the present daily output of 25,000 locks, and an organisation employing, under normal conditions, 1500 men. During these thirty years, almost every important improvement in locks and lock-making machinery, and in kindred lines of hardware, has emanated from the Stamford works, and the Yale & Towne Manufacturing Company's name and trademark have everywhere been accepted as establishing for the goods which bear them the highest standard of excellence in design, workmanship and finish.

In the production of art hardware in great variety and the application of pure art to a class of work which, since the middle ages, had been neglected, Mr. Towne has been conspicuously successful. Of greater professional interest, however, is his work in providing machinery for every process of manufacture, and in organising an industrial system which is considered a model by experts in this line. What this work has accomplished in useful results is shown in the thirteen volumes of the Yale & Towne Manufacturing Company's catalogue, in which more than ten thousand separate articles of manufacture are illustrated and described. It is to be regretted that so little of the exact data at the writer's command touching the details of Mr. Towne's work as a manufacturer can be even referred to in this article.

Mr. Towne has been prominently identified with the great engineering societies and has filled with dignity and grace many positions of honour and responsibility. One of the early members of the American Society of Mechanical Engineers, he became its president in 1888, and was made chairman of the large party of American engineers, representing the three great American engineering societies, which visited Europe in 1889. His contributions to technical literature, standard and current, though mainly relating to his own work in the creation of the plant and business of the Yale & Towne Manufacturing Company, have been brilliant and valuable, showing a scholarly mind, a rare breadth of culture and a clear appreciation of the relation of theory to practice in useful undertakings.

JAMES C. BAYLES.

THE VESUVIUS CABLE RAILWAY

By A. Faerber, Naples

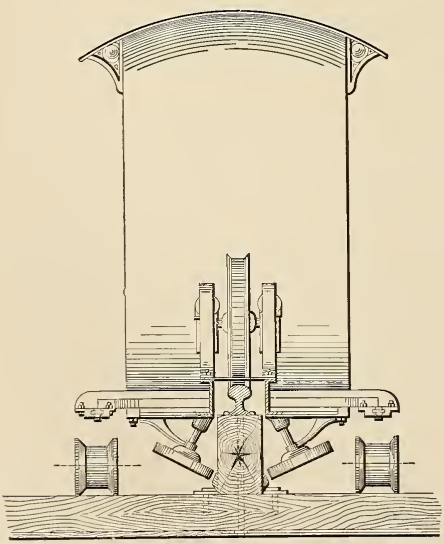
THIS extraordinary cable railway, inaugurated on June 6, 1880, starts from the base of the cone of Vesuvius, and rises nearly to the top platform around the crater. The location of the road, its altitude, and the instability of the ground upon which it is built, created conditions entirely exceptional, which made the work new, and, at the same time, hazardous.

The road has an exceptionally heavy grade, amounting to 63 per cent. along some portions of the line. Others have had the idea of ascending to the crater of Vesuvius by mechanical means, but to Mr. Oblieght, of Hungary, is due the initiative of the present undertaking, upon the completion of which he worked over eight years, taking advantage of the studies of Messrs. Galanti and Wolfort, who had constructed inclined planes in Europe. At last Mr. Oblieght obtained

ONE OF THE CARS

the concession from the Italian Government upon the working plans of Emilio Olivieri, of Milan, and in a very short time the work was carried through.

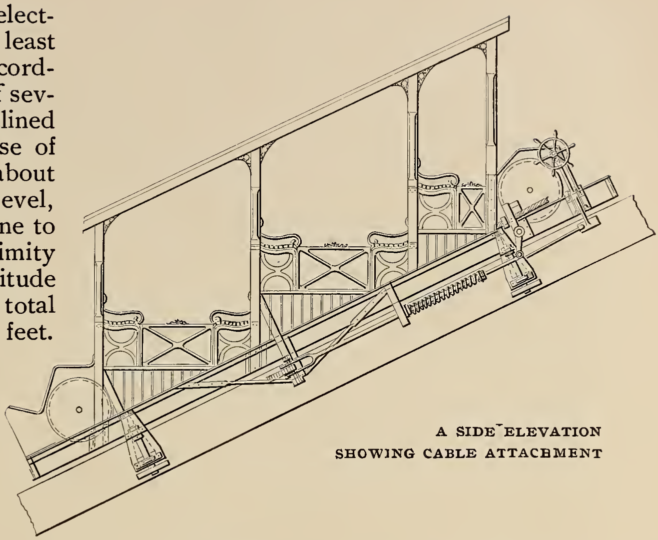
The road starts from under the plazza of the Vesuvian Observatory, at the end of the provincial road, at a point about 2000 feet above the sea level. The latter road zigzags along the western side of the cone for a length of about two miles, with an average grade of a little above 6 per cent., reaching 8 per cent. at only a few points. This road, repeatedly buried by lava during the past three years, but always promptly reconstructed, leads to a platform where the lower station is built. In this are placed the machinery and the rooms for the employees. Another building, of Pompeiian style, on the same platform, is used as a restaurant, and contains one large central room and four smaller ones, besides accommodations for employees. A third building is used as a stable, and in front of it there is a small building for the use of coachmen. On the same level of this platform large reservoirs for water have been constructed.



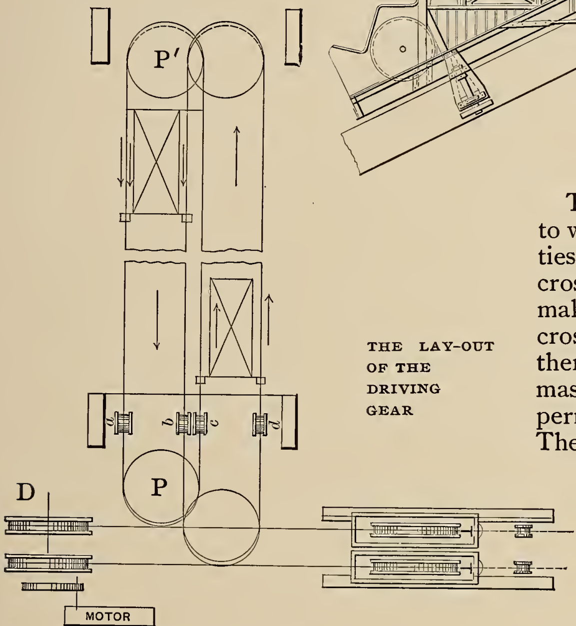
AN END VIEW OF ONE OF THE CARS

The railway was begun in the summer of 1879, and was completed at the end of May, 1880. The line followed by

the inclined plane was selected along the portion least exposed to the lava, according to the experience of several years. The inclined plane starts at the base of the cone of eruption, about 2600 feet above the sea level, and rises in a straight line to the platform in the proximity of the crater, at an altitude of 3750 feet, with a total length of about 2660 feet.



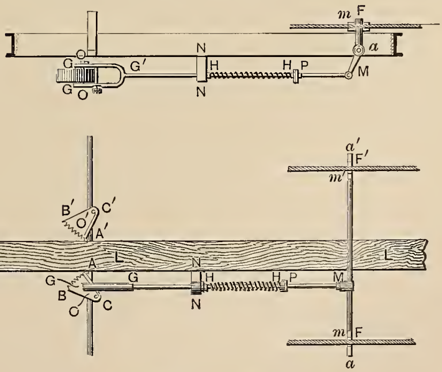
A SIDE ELEVATION
SHOWING CABLE ATTACHMENT



THE LAY-OUT
OF THE
DRIVING
GEAR

At the top there is another small station, from which to the crater there is another walk of about 1300 feet along a slight incline. The maximum grade of the inclined plane is, as stated above, 63 per cent. for a length of about 325 feet; the minimum grade is 40 per cent., and the average grade about 50 per cent. The inclined plane has a double track, each track consisting of one main rail, clamped to a longitudinal wooden sleeper, and two other smaller rails fastened to the lower part of the sides of the same sleeper. The arrangement is shown clearly in the cross-section on the opposite page.

The longitudinal sleepers are bolted to wooden cross-ties, and other wooden ties, placed diagonally between the cross-ties and the longitudinal sleepers, make the system rigid. Upon the cross-ties, which are placed on the lava, there have been built eight stringers of masonry, at variable distances apart, as permitted by the local conditions. These are intended to prevent the sliding of the whole wooden structure upon its foundation, which, at 33 per cent. grade, does not offer much resistance to slipping. The distance between the centers of the two longitudinal sleepers is about 7 feet, and parallel to them, at intervals of



THE AUTOMATIC BRAKE DETAILS

LOOKING UP THE INCLINE

about 50 feet, and on the cross-ties, are placed sheaves for supporting the cables.

The two open cars in use at present are divided into three compartments,—one of two seats, and the other two of four seats each, so that each car can carry ten passengers. Each car is supported by but two wheels, placed one in front of the other like the wheels of a bicycle. To keep the car steady, four small wheels are fixed to the frame of the car, to run upon guide rails clamped to the bottom of the main longitudinal sleeper. Remembering that the road has a grade of 50 per cent., it is apparent that the three compartments cannot be on the same level, but must be placed stairwise upon three different levels. Besides an automatic brake, referred to further on, each car has a powerful hand brake as well, which can be made to grip the center rail.

Each car is hauled by two endless

cables, so arranged that one car ascends while the other descends. The lay-out of the driving gear is shown in one of the diagrams on the preceding pages. The two main rope drums, at the lower station, are driven by a 30 H. P. steam engine. At the right are shown the tension carriages. The cable from the drum, *D*, makes a quarter turn on the sheave, *P*, runs under the small guiding sheave, *c*, passes around the sheave P′ at the upper station, and then returns, passing under the sheave, *a*, and around the tension carriage sheave at the right to complete the circuit. The cable from the other rope drum follows a corresponding path around the other sheaves. While thus, one side of one cable ascends, the other descends, and, therefore, one car is attached to the ascending sides and the other to the descending sides of the cables. When the cars have completed their trip, which takes place in about eight minutes, the engine is reversed, thereby reversing the direction of the ascending and descending cables. The latter are made of steel wire, with a hemp core.

The method of coupling the cars to the cables will be understood from the several diagrams, which also explain the operation of the automatic safety brake previously mentioned. The cables pass through forks, *F*, which form part of the rod, *a a′*. The latter is firmly secured to the car. Into each of the forks, *F*, fits a suitable stop, *m*, fixed to the cable.

The lower bell-crank arm, *M*,—the arrangement, of course, being the same on each side of the main longitudinal sleeper,—operates on a toothed sector, *A B C*, through the intermediary of a rod which is provided with a helical spring. Normally this spring is held under compression between the two stops, *H H*, by the pull of the cables at *F*. Should the cables break, the spring would immediately be released, and force the collar, *P*, and, with it, the rod on which it is mounted, to the right, thus bringing the toothed surface of the sector, *A B C*, against the sleeper, *L*. The grip thus afforded would be amply sufficient to hold the car at any point on the line. Should only one of the cables give way, there would be no action of the brake, and the car could proceed to the end of its trip.

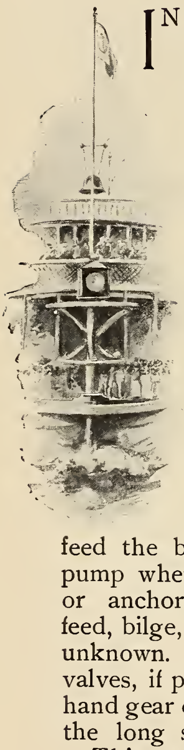
The whole road cost about 650,000 francs, and is owned and operated by Messrs. Thomas Cook & Sons. It was, of course, designed for the service of sight-seeing tourists, and in this service has proved a much appreciated convenience.

A VIEW OF MOUNT VESUVIUS SHOWING THE LINE AND THE STATION BUILDINGS

EARLY MARINE ENGINE CONSTRUCTION AND STEAM NAVIGATION IN THE UNITED STATES

FROM 1807 TO 1850

By Charles H. Haswell, C. and M. E.



IN some reminiscences of early marine engine construction and steam navigation in the United States, presented recently to the Institution of Naval Architects of Great Britain, the writer stated that down to 1822 the engines were of the vertical cross-head type, connected with sliding clutches directly to the water-wheel shafts, and also geared to a shaft with a fly-wheel at each end of it. The object of -the connection was to enable the water-wheels to be disconnected and the engine operated independently to feed the boiler and operate the bilge pump when the vessel was at a pier or anchored, as independent steam, feed, bilge, and fire pumps were then unknown. The steam and exhaust valves, if puppet, were operated by the hand gear of Beighton: when otherwise, the long slide valve was used.

This type of engine, with the cross-head, connecting rods, cranks, and shafts of cast iron, the key, crank, and pin holes cored and cast in, was wholly used until, about the year mentioned, the vertical overhead beam was introduced, and when the horizontal or inclined engine was introduced, the short slide valve was resorted to, except in the Southern and Western waters, where the lever puppet, operated by a cam, was wholly employed.

The boilers, with the exception of the very first few, which were plain cylindrical, set in masonry, were of copper plates of the design termed "D. and Kidney Flue," having but one furnace, the full width of the inner space of the front, the flame and gases of combustion leading through a flue of about two-thirds the width of the furnace into a back connection, and thence into a return flue, which, from the outlines of its transverse section, was termed a "kidney flue." From this they were led to a short vertical flue at the back of the furnace, and then extending up to the shell of the boiler, in a short shoulder of which the base of the smoke pipe was set. The cause of this convexity to the inner side of the main flue, and the indentation given to the inner side of the other, was because the curved surfaces rendered the socket bolts of plain surfaces unnecessary, with the limited steam pressure of 15 pounds or less per square inch.

On Southern and Western waters, where non-condensing engines were resorted to because the waters of the rivers were too turbid for the continuous operation of a condenser, wrought iron cylindrical boilers alone were used and the character of the iron was such that the plates were cold riveted. They were generally internally fired, in some cases externally, and it was not until about 1820 that marine boilers were constructed of iron in Eastern waters.

The boiler plates were punched manually by the aid of a long wooden lever, on which four men exerted their power, and as the location for the punch was directed only by the eye of the oper-

ator, the spaces were frequently irregular, involving pinning, in order to bring the holes as nearly opposite as practicable, and, hence, the plates were frequently strained and the rivets set at an inclination. All of the latter were hand made, but at the East they were driven hot.

Blow offs were not attached to boilers until steam navigation was well advanced. The exact period is not now ascertainable,—probably about 1822. The boilers of steamboats on the bay and river routes, with the low pressure, and the consequent low temperature, of steam with which they were operated, did not involve the necessity of the frequent blowing off of saturated water from their boilers, and the water was allowed to run out of them at the end of each passage. They were then refilled with fresh water. In consequence of this neglect of blowing off, and the imperfect manner in which the plates were riveted, a boiler at the end of a trip in wholly, or even partially, salt water would be loaded in its seams and joints with incrustations and stalactites of salt to an extent that involved their being hammered and scraped off. Felting of a boiler was unknown.

So deficient were the facilities of lathes, planers, slotters, and drills, that "black work" of engines, as it was termed, was the prevailing finish. The connecting rod of a large vertical beam engine in the *Victory* was wholly finished in the smith's shop, its body, after forging, being dressed by swaging, the key holes drifted, and the ends and straps dressed with a flatter on an anvil, and a horse file.

Cylinder piston packing consisted of hemp gaskets, and, if the safety valve of the boiler was not raised during the initial raising of steam, the steam around the chimney flue would become so dry as to char the wood blocking between the ribs of the piston, and also the piston packing; hence lead pipes, through which the gaskets were drawn, were resorted to.

Counters, indicators, salinometers, brine pumps, steam and vacuum gauges, metallic packing, whistles, and oil cups, other than the one in the cylinder head, by which the piston was lubricated on its exhaust side, were unknown.

About 1824 James P. Allaire, of New York, constructed the steamboat *Henry Eckford*, with a vertical cross-head compound engine, the centre shafts geared to the wheel shafts; but, in the absence of a receiver, the mutual operations of the cylinders were only at the extreme of the opposite strokes of their pistons. Soon after, and up to 1828, he constructed five other boats, namely, the *Sun*, *Commerce*, *Swiftsure*, and *Pilot Boy*, with like engines, and the *Post Boy* with an overhead beam engine, the cylinders being set at its opposite ends; but, as this type of compound engine operated at the moderate pressure of but 25 pounds per square inch, it did not attain such an effect as to justify the increased cost and weight of two cylinders and their connection, and its further construction was abandoned.

In 1827 Mr. Allaire invented the steam chimney. The original design was that of two cylinders of boiler plate, one within the other, connected and closed at both ends, the inter-space being about 5 inches in width, with a vertical diaphragm, connected near its upper end to the outer shell above, where steam was admitted from the boiler through two or more connecting pipes. These served also as fastenings and to hold the chimney in position. This diaphragm led down to within a few inches of the bottom of the chimney, and the steam was inducted down and under it, then up and around the inner cylinder, and thence to the steam pipe opening in the top; thus the steam deposited its contained water in the chimney, to be vaporised by the heat at the base, and received also heat from that ascending the chimney; hence a material economy of fuel was attained with the advantage of obtaining dry steam. Boilers at this period did not foam (prime); the great proportionate volume of water, its area at the water-line, and the moderate heat in the furnace, from wood, with but a natural draught, precluded it.

In 1828 the engine of a large steam-

boat, the *Chief Justice Marshall*, on the route from New York to Albany, broke down by the breaking of the head of her piston rod at its insertion into the cross-head socket; the cross-head, both connecting rods, and a centre crank were broken, and in four days new castings from the builder's patterns were made, the piston rod was repaired, all fitted, and the engine was ready for operation. In this connection it is to be considered that neither the eye of the crank was reamed nor the key-holes of the rods slotted; the crank eye and the ends of the rods were submitted only to the operation of a coarse file.

In the attachments to engines and boilers the steam gauges were constructed in the smith's shop, and consisted of an iron tube half an inch in diameter and 4 feet in length, bent, with one of its legs 15 inches in the clear in length, and in the other the balance of its length was filled with mercury, on which was placed a light pine rod, the rise and fall of which, shown on a tin plate divided and numbered in inches, designated the pressure of the steam in pounds per square inch.

Steam navigation, up to the latter part of 1839, was confined to Long Island sound, the Southern and Western rivers, and Canadian lakes and rivers, with a single passage of a steamboat from New York to Philadelphia, the *Phœnix*, in 1807, and one on the route from Havana to Matanzas, and one from Charleston to Savannah. In 1819 the auxiliary steamer *Savannah*, of 380 tons, steamed and sailed from Savannah to Liverpool, she being the first steamer to cross the Atlantic ocean.

In 1825 Mowatt Brothers, of New York, owners of the steamboat *Henry Eckford*, attached a loaded barge to her, and transported it from New York to Albany; this was the first essay of steam towing, and, although its insufficiency and impracticability were generally predicted, the enterprise proved to be a great and lasting success.

In 1826 a fan blower was first introduced under the grates of the boilers in the steamboat *North America* of the Messrs. John C. & Robert L. Stevens.

In 1828-1829 the rivalry for speed between the steamboats plying on the route from New York to Albany was so great that, in the design of the boats, their beam was disproportionate to the weight of the engine, boilers, and deckhouses above, and they proved unstable. In order to reduce this condition, large logs of light pine wood with sharp ends were firmly suspended under the after wheel-guards and depressed for half of their diameter below the water line, and in operation they measurably improved the stability of the boat.

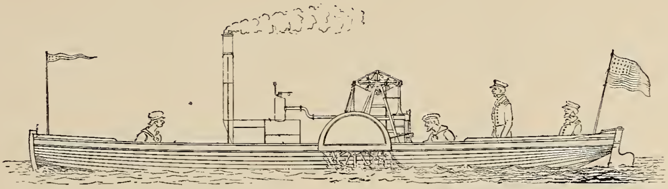
In 1830 the patent of the steam chimney of Mr. Allaire was invaded, and its operation simplified by making the double cylinder an integral part of the boiler, open at its lower end, and extending to such a height above the boiler as to give the necessary surface to superheat the steam. The height and volume of steam space helped measurably to arrest foaming, by admitting the subsidence of the water physically borne with the steam in its flow to the steam pipe.

Gongs for the engine room were unknown, and in many of the boats, when the pilot was in his house (if there was one) or on the deck over the engine room, he would signal to the engineer by the strokes of a stick or cane upon the floor of the house or deck. All boats of course carried bells, and by them all notices of departure and of arriving were made known, and all salutes between boats were given by their bells. To blow steam, as is now done by a whistle, was intended to be a challenge or an insult.

In July, 1837, the first steam launch, the *Sweetheart*, 35 feet in length, 4 feet 3 inches beam, and 3 feet depth, engine 4 × 12 inches, wheels 3 feet 6 inches in diameter, and boiler horizontal firetubular, designed and constructed at the United States Navy Yard, New York, by the writer, then chief engineer of the navy, was completed, and on her trial and succeeding trips around the city of New York was saluted with the bells of passing steamboats and cheered by people who rushed to the ends of the piers to witness the novel sight. She

attained a speed of 8.5 miles per hour. The engine was subsequently transferred to the United States Naval School at Annapolis.

Fuel, up to the year 1836, was wholly pine wood, though up to that time some owners of steamboats commenced experimenting upon the practicability of using anthracite coal. A steamboat on her route of six or more hours could not have the capacity in her fire-room to contain all the wood required, and was compelled to pile it upon her side houses; and such boats as were on a long route, as from New York to Providence, were compelled to invade their upper deck with wood, and upon leaving the city, had somewhat the semblance of a floating woodyard.



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THE STEAM LAUNCH "SWEETHEART," 1837

In 1836 James P. Allaire commenced the running of a steamboat, the *David Brown*, a light-built river boat with deckhouses and promenade deck, from New York to Charleston, S. C., and return, the enterprise being almost universally held to be utterly impracticable. It was successful, however, and soon afterwards he built two other and larger boats for the same route, and, from that period, coastwise steam navigation was held to be so practicable that various lines to other ports were established. The *David Brown* was fitted for this new service with planking under her water-wheel guards closely joined and calked, extending from the inside of the string-piece to the light water-line, which shielded the guards from being forced up by a sea. This device, after several essays at a proper term, is now known as the sponson. In some cases on coast routes, instead of a closed shield, open slatting was resorted to.

The first propeller steamer was introduced in 1837. In 1838 Phineas Bennett designed, patented, and introduced in the steamboat *Novelty*, plying on the Hudson river, a vertical cylindrical boiler in which a hermetically closed furnace was supplied with air by a pump, and all the gaseous products of combustion of the fuel were driven into the steam-room of the boiler; the object of this design was to increase the generation of steam and reduce the proportionate area of heating surface. The boiler was removed after a short period of service.

Soon afterwards Bennett introduced the design into a vessel built to ply between New York and Liverpool, under the conditions with her builder that, if the design proved to be acceptably successful, he was to be paid for the entire plant of engines and boilers and his services, but if not successful he was to remove the entire plant, and at his own expense, without any remuneration whatever. The engines and boilers were completed and operated, but they were not paid for by the builder of the vessel, and the boilers were soon after removed and replaced with others. In consequence of the ashes, borne into the valve chests and cylinders, and the evaporation of the oil of lubrication by the heat of the steam, the valves were rapidly worn, and the cylinder pistons shrieked to a degree that would have rendered the design very objectionable, even if it had been successful in other points.

Captain John Ericsson arrived in New York in this year, and in 1842 he designed and directed the construction of the engines and propeller for the United

States auxiliary bark rigged steamer *Princeton*.

In 1839 anthracite coal was introduced in the furnaces of the steamboat *North America* plying on the Hudson River between New York and Albany, and, to aid its combustion when a high pressure of steam was required, a fan blower, driven by a belt from the wheel shaft, was first resorted to, but soon afterwards a small independent engine was used, connected by a belt to the blower. Anthracite coal was soon afterwards first burned without auxiliary draught in the open furnace of a steam boiler.

Wrought-iron shafts were first made in 1840, the construction varying wholly from that of the present period; thus, iron bars from 2.5 inches to 3 inches square and of the greatest attainable length, were laid up with a square section, the abutting ends breaking joints with the other bars; hence, the solidity of a section of the mass was subjected only to any imperfection arising from their ends not being wholly welded, by the percentage of the section of one bar to the whole number, and of all the shafts made up to the period included in this paper, only one was broken, and that in consequence of its being insufficient in diameter for the stress to which it was subjected. This result was foretold by the writer when the diameter of the shaft was reduced from that given in the specifications.

The first steam frigates for the United States were constructed in 1843.

Captain John Ericsson applied a surface condenser to the engine of a revenue cutter in 1846, and in 1848 Pierson designed an improvement of it which was further improved by Chief Engineer William Sewell, of the United States Navy, and the perfected instrument is now in general if not in universal use.

The *Atlantic* and *Pacific* of the New York and Liverpool S. S. Company, "Collins Line," were constructed in the year 1848, and in July, 1850, the *Atlantic* made the then quickest passage between New York and Liverpool, it having taken but ten days and fifteen hours. The *Arctic* and *Baltic* of the same line were launched in the same year.

It was wholly impracticable to obtain the consumption of fuel per indicated horse-power in early steam engineering, as engines were not fitted with counters or indicators and the wood was not weighed. In 1840, with auxiliary or blower draught, and in the absence of counters and indicators, it was computed by weighing the coal consumed, and held to be about 5 pounds, and the speed of the river boats from 8½ statute miles in 1816 increased to 19 miles.

Current Topics

ONE obstacle to the more rapid adoption of electric power, especially in the case of small users everywhere, is undoubtedly the want of capital to purchase the necessary motor; but where the power to purchase exists, the buyer often has little or no experience with electrical matters to guide him in his purchase, and if his means are limited he will naturally be tempted to venture on a cheap line with probably unsatisfactory results. A solution of these difficulties, which has been applied with excellent results at Bradford, England, is the purchase of good, reliable motors, and offering them for hire by the owners of the electricity supply undertakings, who, in this instance, are the municipality itself. According to figures prepared by Mr. Alfred H. Gibbings, the city electrical engineer of Bradford, they have found there that a rental charge of 10 per cent. upon the initial cost of each motor was amply sufficient to yield acceptable returns, this charge being made up of 3 per cent. for interest, 3 per cent. for sinking fund, and 4 per cent. for depreciation and contingent expenses. The Bradford Corporation inaugurated their scheme of hiring,—in which, by the way, arc lamps also are included on similar terms,—in November, 1896, and up to October of this year had supplied 98 motors to consumers. The increase in electricity supplied for motive power in 1896, with only two months of the hire system in force, over that supplied in 1895 was a little over 19,000 Board of Trade units; in 1897 the increased sale over 1896 was over 52,000 units, and for this year the increase over 1897 will probably be nearly 63,000 units, representing a more than 50 per cent. increase. These figures show very strikingly to what extent the facilities offered by the Bradford Corporation are appreciated. Hitherto the supply has been confined to small power uses, such as for cranes, hoists, fans, pumping and similar purposes. More recently, however, applications for motor service have come from a large spinning and weaving firm, several foundries where blowers are to be driven, a saw-mill requiring about 20 horse-power, and an engineering shop requiring about 50 horse-power, all of which indicates growing and gratifying confidence in electric power.

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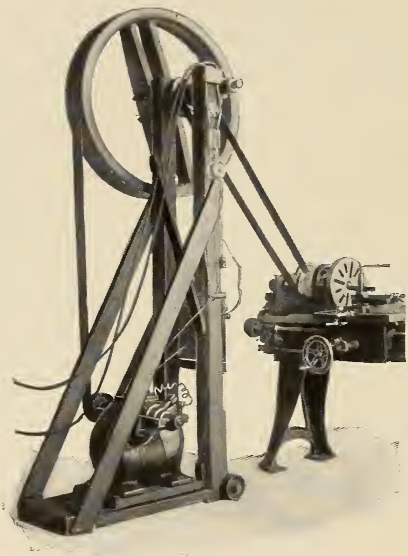
WHAT will strike most people as an original and a very convenient arrangement of portable electric motor is shown in the illustration on the next page. It

represents an outfit,—home-made, it may be termed, since it was not intended for sale,—which is used in the shops of the H. C. Fish Machine Works, at Worcester, Mass., princpally for testing machine tools. The usual plan of lending ready portability to an electric motor is simply to put it on a small truck, on which it can be wheeled about, and to provide switches in the general circuit so that the motor can be connected and operated at convenient points. In the arrangement shown, the motor is mounted on the base of a wooden frame



A PORTABLE ELECTRIC MOTOR

of simple design. In the upper part of this is a shaft carrying a large split pulley and also a cone pulley, the belt from the armature shaft passing around the large pulley. From the cone pulley a belt leads off to the particular tool to be driven. The two small wheels shown on the base of the frame, just clear of the floor, are for use when moving the device around the shop. The frame is simply tipped forward until these wheels touch the floor, when it becomes its own truck. The lighting system of the works can be tapped at any desired location. The total cost of the affair was trifling, and the service that has een given by it has been excellent.

An excellent illustration of the fact that it costs much more to heat the fresh air that must be supplied for good ventilation than merely to maintain the temperature of a room or building is afforded by the heating ventilating plant of the new buildings of Columbia University, in New York City. These buildings, according to *Engineering News*, are supplied with enough direct steam radiators to overcome the loss of heat through walls and windows, and the entering fresh air for ventilation is blown over stacks of heating pipes, so that it goes into the rooms at a temperature of about 70 degrees. The buildings have a total cubic contents of about 9,700,000 cubic feet, the heating surface in the direct steam radiators is about 56,000 square feet, and the ventilating system is designed to furnish about 50,000,000 cubic feet of air per hour. When the outside air is at zero, the steam consumption of the plant is estimated as follows, in horse-power:—Condensed in direct-heating radiators, 560 horse-power; condensed in heating stacks in connection with blowers, 2205 horse-power; power required for electric motors, operating, blowing and exhaust fans, 635 horse-power. In other words, the heating and distribution of the fresh air for ventilation takes about six times as much coal as is required to simply maintain the inside temperature of the buildings. In a lecture describing this plant, delivered before the Engineering Society of Columbia University, Mr. G. A. Suter, under whose direction the installation was carried out, gives the following useful figures from the experience with this plant:—One horse-power of steam supplies 100 square feet direct radiating surface. One horse-power-hour of steam supply heats 20,000 cubic feet of air from zero to 70 degrees F. One horse-power on the shaft of an electric motor driving a blower will move 75,000 cubic feet of air per hour into and out of the rooms. The very large amount of power required for moving the air will be, probably, a surprise to many engineers, but it is to be remembered that as all the exhaust steam is utilised for heating,

and the power applied to the air, for the most part, also appears as heat, the fan system of heating and ventilating is really not so expensive in operation as might at first sight appear.

APROPOS of the creation and maintenance of foreign markets for machinery, or for general supplies, to which reference has previously been made in these pages, it is interesting to read what the United States consul at Shanghai says, in a recent report, concerning some of the eccentricities of Chinese buyers. His remarks are in the nature of advice to American exporting firms, but are quite as interesting from a general point of view. He finds, to begin with, two great obstacles in the way of Chinese business with America. In the first place, American firms do not take care to fill the orders exactly. There is somewhat of a feeling in the United States that "anything will do for the Chinese." As a matter of fact, there are no people more particular than the Chinese. Their customs and their superstitions must be considered, as well as the things which come into account in other countries. It is a great thing to have a lucky trademark. It is, above all, necessary to handle the goods through a man on the ground, in whom the Chinese have confidence. They do not think anything about the firm at home; they think of the man directly with whom they deal. This man, if he is wise, knows the demands of the trade and caters to them, and, however eccentric some of his directions may seem in ordering, they should be followed to the letter. In the next place, almost all British and German firms have an arrangement by which claims for damages through faulty packing, or from other causes, are settled promptly, through the arbitration of their consul, at the place where the goods are delivered. Most American shipments are made without any such agreement, and the result is that should the goods be damaged, those interested are so far apart that the local dealer in China is forced to stand the loss, rather than to go to the expense of suit or arbitration in America. The consequence is that on even terms or at some difference in price he buys his goods from Great Britain or Germany. He is willing to pay the higher price for a certainty of a speedy, just and inexpensive settlement of any damage there may be.

THE Belgian consul at Shanghai, writing on allied lines, says that the indispensable intermediary, or "middleman," between the European and Chinese traders is the "compradore," whose name is derived from the Spanish *comprador*—*i. e.*, buyer. The earliest foreigners who came to settle in China for purposes of trade, carried on business on the principle of exchange only, receiving merchandise in return for that which they brought with them, and the interior of China being closed to foreigners, they were obliged to have recourse to intermediaries to procure what they required. This method has been adhered to, and attained its greatest importance at the time of the "merchant princes," whose profits were so enormous that the heads of foreign firms did not condescend to occupy themselves with their business, but left the conduct of their affairs to their "compradores." The desire of the Chinese to obtain large profits, and the carelessness evinced in the direction of affairs on the part of the Europeans, combined to bring about the inevitable state of affairs, viz., that a large portion of the profits were pocketed by the "compradores." Not only the purchases, but the sales also, were intrusted to them, and, as an explanation of such a state of affairs, it was urged that the Chinese language is difficult, that the Chinese pay with bills at long dates on banks in the interior of China, and that, consequently, a man of business was required, conversant with the commercial customs of the country; but the true reason was that, notwithstanding the personal pickings of the "compra-

dores,'' the profits were so large that they went into business affairs only when they had the time. The result was, as stated, that the "compradores" amassed wealth and gained the important position which is theirs to-day.

At the present time the method of conducting business has completely changed; the merchant princes have disappeared from the scene, leaving only the memory of a time of profits and extravagance. Telegraphic communications and the opening up of rapid and easy routes by steam, especially by means of the Suez canal, have introduced a new generation in the Chinese markets, with small capital and sometimes none at all, but with a love of work and a spirit of economy. An enormous competition has been created among these newcomers—all workers—a keen, constant struggle, in which the old wealthy firms succumbed. The rôle of the "compradore" has thus been modified; he continues, as before, to hold all the business in his hands, both in the buying and selling markets; but to these professions he has added an important one,—that of money lender.

Under such conditions, and considering the mercantile spirit of the Chinaman, it may be concluded that the firm who employ the "compradore" serve for him simply as a means of speculation. It may be asked why this costly and ruinous middleman is not suppressed; and it may be answered, because it is impossible, and because a firm who had no "compradore" would do no business. These middlemen have been incorporated for a long time; their corporation is the richest and most important in all China, and any merchant wishing to do business with a foreign firm must deal first with the "compradores." If a trader tries to trade direct, he is annoyed in so many ways that he hastens to return to what are called "old customs," and China, it should be remembered, is an essentially conservative country where an established custom has the force of law. The consul adds:—"It may be seen, therefore, that the guild of 'compradores' is a commercial institution in China, and that it is useless to think of suppressing it or diminishing its importance."

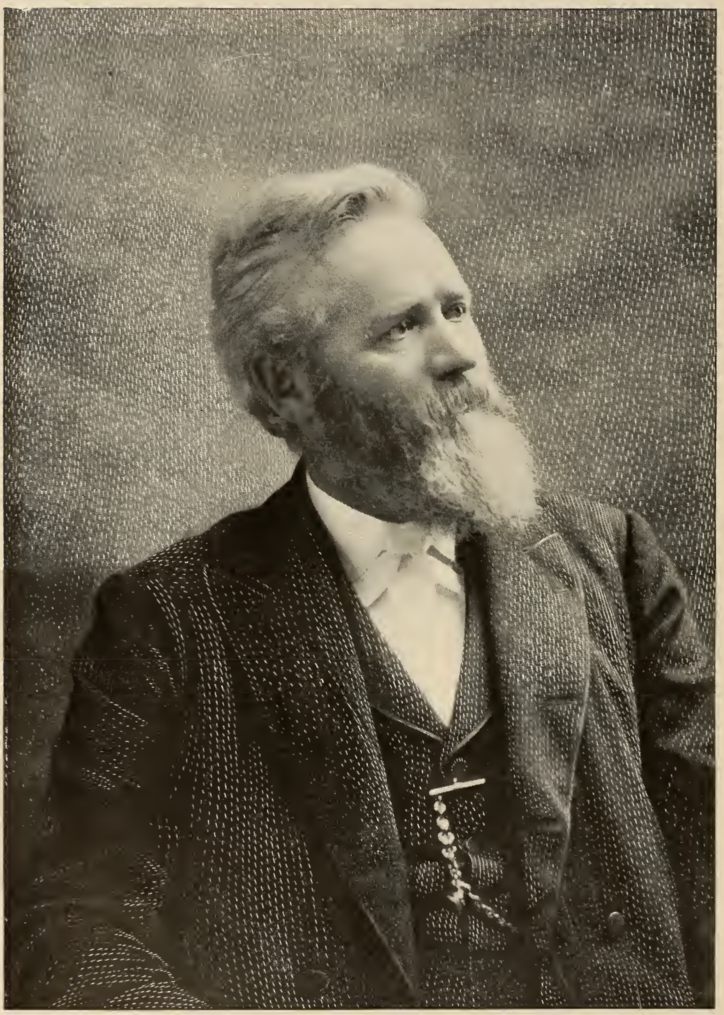


PHOTO BY MORSE SAN FRANCISCO

Yours Truly
G. W. Dickie

GENERAL MANAGER OF THE UNION IRON WORKS, SAN FRANCISCO

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BLOCK-SETTING TITAN CRANES

By Joseph Horner

ONE result of the employment of concrete blocks of large dimensions in place of hewn stone and rubble for the building of harbours and piers, has been the development of an entirely new class of cranes, designed especially for the hauling and setting of these blocks. These have largely superseded the older methods of erecting temporary and removable staging at the sea front, from which to deposit masonry, and also the floating plant for depositing large blocks in deep water.

The block-setting cranes have been constructed to lift working loads of from about fifteen tons to seventy tons. They are, in fact, huge machines which travel bodily, hoist, lower, and rack, and in numerous cases also slew through a portion of, or around, a complete circle; or they are designed to cross traverse in a greater or less degree, without the capacity for slewing. These have been variously termed "Titan" cranes, "Hercules" cranes, "Mammoth" cranes, and "block-setting" cranes, named thus in the sequence of time. The first one, "Titan," has survived, and is that which is commonly employed as a generic term to denote any huge block-setter, without much regard to its details of design or construction.

The writer worked upon the first English block-setting crane ever made, about the year 1869; and he has also had a good deal of work to do with the construction of more than a dozen since. Many improvements have been effected in their design and construction during the thirty years or thereabouts in which they have been developing. These are of such special types, and so little is known of them, that some account of their leading features may prove of interest to many readers.

The concrete employed for the construction of harbour works is deposited either in bags, or in hardened cubical blocks, which, ranging from about fifteen tons to seventy tons each in weight in many instances, require hoisting machinery which will be capable not only of lifting such masses, but also of carrying them along and depositing them to a considerable distance ahead of the machine itself. Obviously the bridge type of crane, whether it be traveller, or goliath, is not suitable for such serv-

THE PORT OF SUNDERLAND, ENGLAND

ice, because each of these can hoist and deposit only directly underneath the bridge, or the gantry. These, though employed in modern harbour work, are of service only as transporting, and not as block-setting, agents.

The cranes used, therefore, must be jib cranes, as well as travelling cranes. Derrick cranes have been used for block-setting, but almost the only recommendation which they possess is that of cheapness. The shortness of their radius necessitates frequent refixing, which causes delay and costs money, while the necessary provision for maintaining due relation between the height of the load and the radius of the jib introduces objectionable details in construction and operation. Derrick cranes, however, are so handy that some engineers have preferred to use them for setting the side blocks, using a rigid or non-revolving Titan for the end work. Since the quays, piers, or breakwaters are wider than the cranes employed in building them, it is necessary to use a side setting crane, or to make the jibs either of the radiating or of the revolving type, so that blocks may be set to right or left as well as straight forward; or alternatively, to use a rigid Titan with a cross traverse wider than the pier.

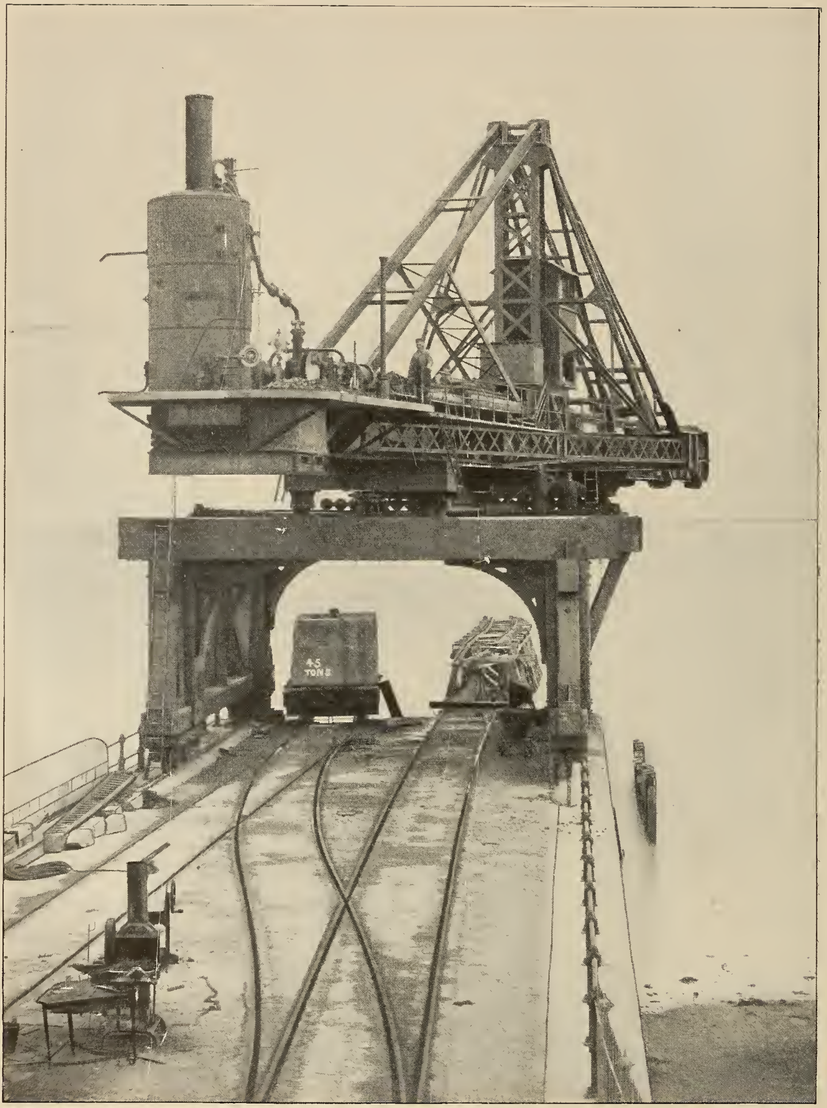
The road upon which the crane travels has to be made as the work proceeds, and the blocks must be set sufficiently far in advance of the wheel-base of the crane to insure a firm foundation for the latter. A maximum radius of from about forty to a hundred feet is, therefore, given to cranes of this type. These results then follow:—Since the cranes have to travel, they must be balanced cranes. The overhang of the jib being considerable, and the load massive, the wheel-base must be long in order to insure safety and stability during travelling, hoisting, and slewing. Sufficient material should be massed over, and within, the wheel-base and gauge to bring the centre of gravity within the path on which the crane rotates. If these fundamental requirements are observed, the details of design of block-setting cranes may be varied in a wide degree, as will be illustrated in the following pages.

The regular type of block-setter always has a horizontal jib along which the jenny travels with the load to any radius within the range of the jib, similarly to the jenny on the triangular framed type of foundry crane. The jib is made either of sufficient depth to be capable of resisting the strains due to the load and its leverage, or it is supported by means of tie rods anchored to a king post, and with a queen post and bracing behind. The first type of jib is of cantilever form, of approximately semi-parabolic outlines; the second is built of parallel girders, solid plated, and single-webbed, or else boxed up. The cantilever girders are likewise made solid plated in small and large machines alike, but they are also as often lattice braced.

The first large Titan which was constructed, that for Karachee Harbour, was made thus. The nature and extent of the stresses in braced girders were not so fully understood then as now, and the writer remembers that the effect of a crippling load was tested by small models of the braced girders cast in lead. The material used in the machine was wrought iron,—mild steel being at that time a new material, which was also costly.

This Titan was followed by another for East London, in which the jib was supported by tension rods,—probably the first of that type,—the jib being a single boom instead of double. Both these types, namely, the self-sustaining cantilever jib, and the jib sustained with tie rods, are, with many modifications, representative of the lines on which subsequent block-setters have mostly been built.

Respecting the methods of movement adopted, there are also three main types, — the rigid-framed machine, which does not revolve, but travels forward only; the machine which both travels and revolves, turning through a portion of a circle only; and that which revolves through a complete circle. The Karachee Titan was of the first type. This type was also represented in one of



A 60-TON TITAN USED IN BUILDING THE HARBOUR PROTECTING PIERS AT THE PORT OF SUNDERLAND. CONSTRUCTED BY MESSRS. JESSOP & APPLEBY BROS., LEICESTER, ENGLAND

the early Titans used on the Colombo Harbour works so long ago as 1877. The superstructure traversed across the bottom framing. The latter comprised two cross gantries, 43 feet in length, carried on timber side frames, having a gauge of 29 feet. The framing travelled longitudinally, and the superstructure and jib traversed across to cover the whole width of the breakwater. The overhang of the transverse gantries permitted this,—diagonal brackets coming down to the lower part of the framing sustaining the overhanging ends.

The East London machine was of the second type, a design which has been repeated, as far as the limited radial movement is concerned, in about half a dozen cases. The first one of the third type was built in the years 1880-81,

for the North pier of Tynemouth, and was subsequently duplicated, without modification, for the South pier also.

The Tynemouth "Mammoths," as they were christened, differed in many respects from any which had been previously constructed. The main frames were entirely of timber, brought from Vancouver Island, the only locality where balks of sufficient dimensions could be obtained. The timbers in the main jib were 3 feet 6 inches deep; the width the writer believes, was 2 feet 6 inches, and each boom was made up of two thicknesses of balk bolted together. The bottom framework was also wholly of timber, the wheels, tie rods, and machinery only being of iron. One side of the main framing was lower than the other, so that while one set of wheels ran on the pier, the other set ran on a parapet. The working load was 40 tons at 95 feet radius. An elaborate model of this machine was constructed under the writer's supervision, and formed a portion of the exhibits at the North East Coast Exhibition in 1882.

Since that time a good many block-setters have been made of the fully revolving type, the convenience of which arrangement more than counterbalances the additional cost when there is a great length of breakwater or pier to be constructed. The advantages are that such Titans are capable of setting blocks at the sides as well as straight ahead, and that they can pick up concrete blocks from the rear, slew them around, and set them in front, or at the sides. They will also command a greater width of pier than the rigid type, unless the latter are designed on the lines of the Colombo machine just now instanced, in which the cross gantries are made to overhang the longitudinal frames on which they travel.

The three main types which were evolved in the first ten or twelve years of Titan design are those upon which, with a very few exceptions, all subsequent block-setting machines have been built.

The powerful Mammoths at Tynemouth were soon followed by one even more powerful at Sunderland, made to the designs of Mr. H. Wake, the engineer to the River Wear Commission,

A 100-TON ELECTRIC TITAN CRANE BUILT BY MESSRS. JESSOP & APPLEBY BROS.

FRONT VIEW OF A 60-TON CRANE USED AT THE PORT OF SUNDERLAND

to deal with 45-ton blocks. This appears to have been the first machine of this general type in which the wheels were fitted with volute springs, of which there were four to each wheel. Its jib was of the braced type, the tension rods being each composed of a pair of channel bars set back to back. The bottom framing was of timber, and the superstructure of wrought iron. But the special feature of the crane lay in the method of its operation, which was by hydraulic power,—apparently the only Titan yet made in which all motions have been thus operated. The lifting was effected by means of three cylinders; the slewing by two others, the machine being of the radiating type; while the jenny was traversed by a couple more. Chains were used for the lifting and lowering, and wire rope for the other motions. This appears to have been the first application of wire rope to these machines, the Tynemouth ones being operated entirely by chain.

In one instance electric power was applied to the operation of a Titan. It was in the case of work carried out at Bilbao Harbour, in Spain, by a firm of French contractors. The machine was designed for dealing with 10-ton blocks, and its overhang was 66 feet. It was a rectangular, framed structure, comprising two main girders, lattice braced, united with cross girders, and carrying three platforms. On the upper one a revolving jib crane,—the actual block setter,—travelled; while the lower platforms were utilised for a concrete mixer, motors, elevators for dredging, etc. The Titan rested on sixteen wheels on two sets of rails of 2 feet 3 inches gauge each, and 10 feet centre to centre. The current for the motors was supplied from a 24,000-watt dynamo, at 220 volts, driven by a 35 horse-power semi-portable engine, and bare copper conductors were used. The efficiency was 65 per cent.

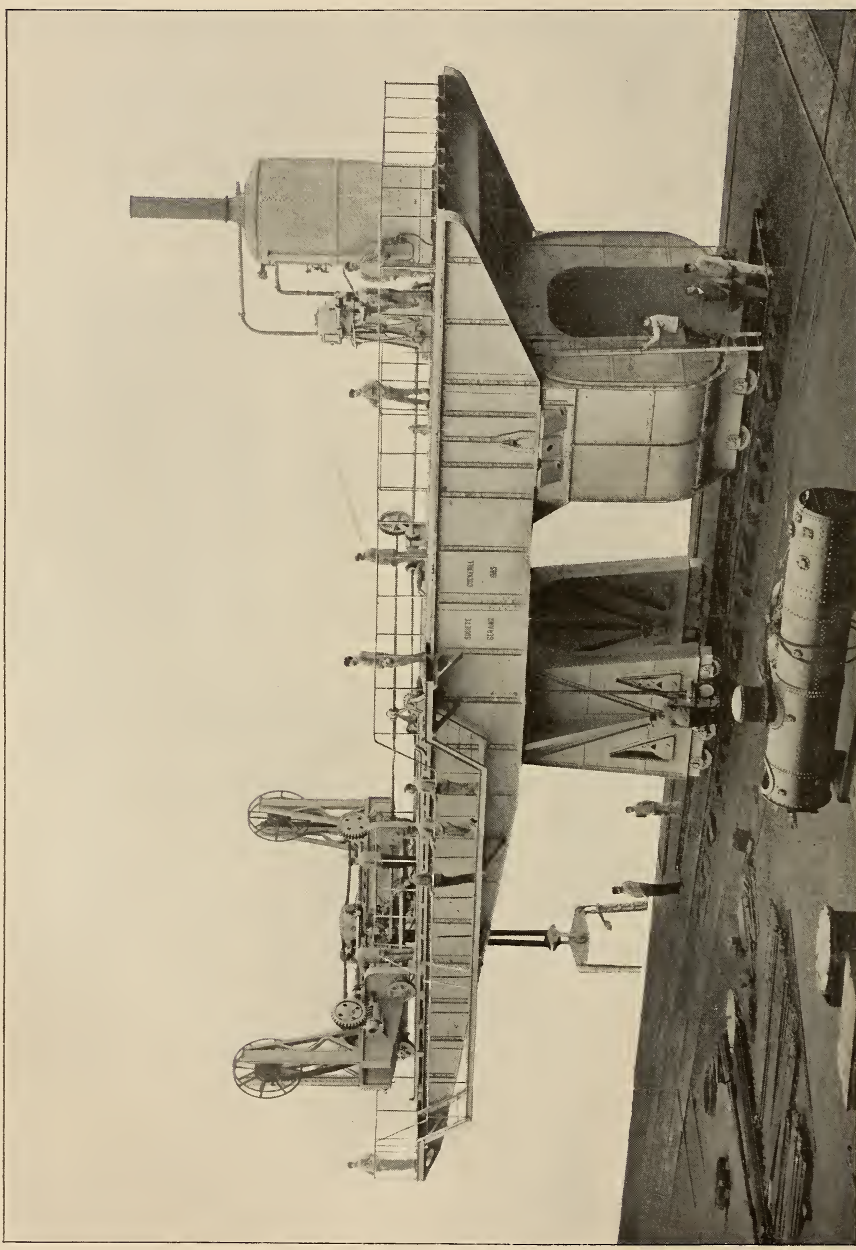
Though this is probably the only instance of the application of electricity as a motive force to the operation of this particular type of machine, yet there is no reason why it should not extend, as it is doing in the case of overhead travellers and machine tools.

A block-setter of only 6 tons capacity has been made, but this is very exceptional. Among the smallest block-setters ever made are those for East London and Port Alfred, of 15 tons capacity. Among the largest are the machines at Tynemouth, Sunderland, and Peterhead; and that at Leixses, in Portugal, and one at Vera Cruz.

Having thus briefly outlined the history, and indicated the general principles of design of the Titans, the methods of construction of the several portions of these machines can be best understood by considering the several sections in brief detail. These include the main frame, or truck; the jib; the hoisting, traversing, travelling, and subsidiary operating gears, and the engines.

The main framing, or truck, was, as already noted, made in some of the earlier machines of timber balks. But that practice is now exceptional. Wrought iron was also employed until mild steel supplanted it, and wrought iron is not now used. The construction of the framing varies with requirements. Two 15-ton block-setters, similar to each other in all respects, built nearly twenty years ago for the South African harbours of East London and Port Alfred to the design of the late Sir John Coode, had trucks almost identical with those of standard portable cranes,—that is, they were built with solid webbed girders,—sides and ends being united to form an open frame, the whole lying low down nearly over the running wheels. These were rotative cranes, so that there was no objection to the low position of the trucks.

Generally now, however, the framings are brought up sufficiently high to permit of the passage, underneath, of the trucks which bring the concrete blocks from the yard in the rear. In this way the blocks are brought right underneath the hook of the jenny, which picks them up, and racks them along to the point of deposition. This practice, adopted first for obvious reasons in the case of the rigid machines, has been followed in the revolving ones, because of its



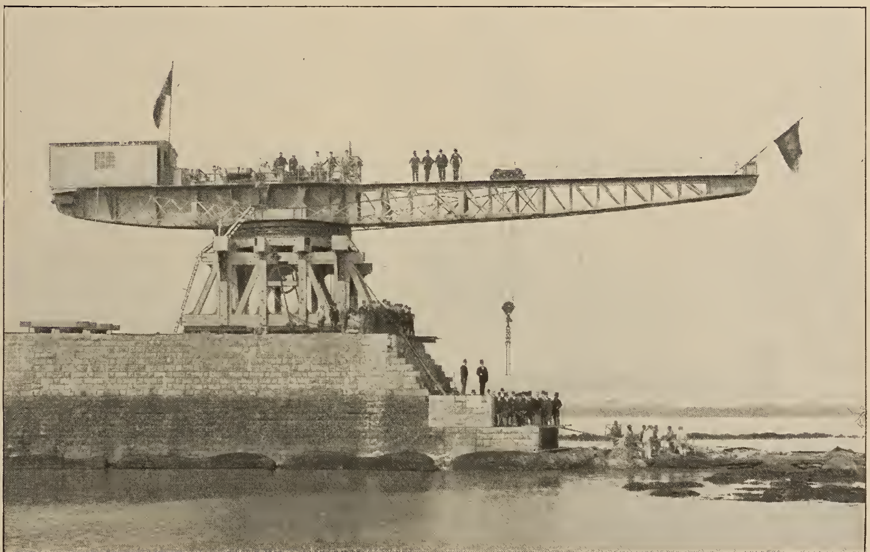
A 40-TON TITAN CRANE BUILT BY THE SOCIÉTÉ JOHN COCKERILL SERAING, BELGIUM

general convenience. It is better to have a clear way under such machines, as in the case of many cranes on dock walls, wharves, and piers, than to have a low truck blocking the way.

Again, many piers, as at Tynemouth, have a parapet wall running the whole length, and that necessitates making one side of the framing with its wheels higher than the other,—one set of wheels running on the parapet. Such machines are always made of sufficient height to allow a clear headway for trucks beneath.

The structure generally comprises a pair of braced framings united by transverse girders, upon which the jib is built solidly, or upon which it revolves. Angle brackets are inserted to stiffen the union of the side frames and the cross girders, and similar brackets are fitted in horizontal positions, or a circular girder is superimposed, so preventing liability to cross or diagonal working in any direction. The top and bottom booms of the side framings, and often the upright posts, too, are in most machines solid-webbed box girders. The diagonals are generally single-webbed. The circular girders are either single or double webbed,—dependent upon the size of a given machine.

The whole framework is rigid, calculated to be steady under the stresses due to the dead load of the crane above, and to the leverage of the maximum load lifted. It must also have a wheel-base sufficiently long, and a gauge sufficiently wide to be absolutely stable under the lifting of maximum loads, apart from any aid to be afforded by rail clips or blocking girders, which may or may not be used. The fulfillment of these conditions involves massive constructions, good fitting of joints, and high-class workmanship, and the bringing of the centre of gravity of the machine well within the circular girders when the maximum load is being lifted at maximum radius, or when the machine is empty, with the weight of ballast behind.



A 25-TON RADIAL BLOCK-SETTING CRANE, WORKED BY A GAS ENGINE

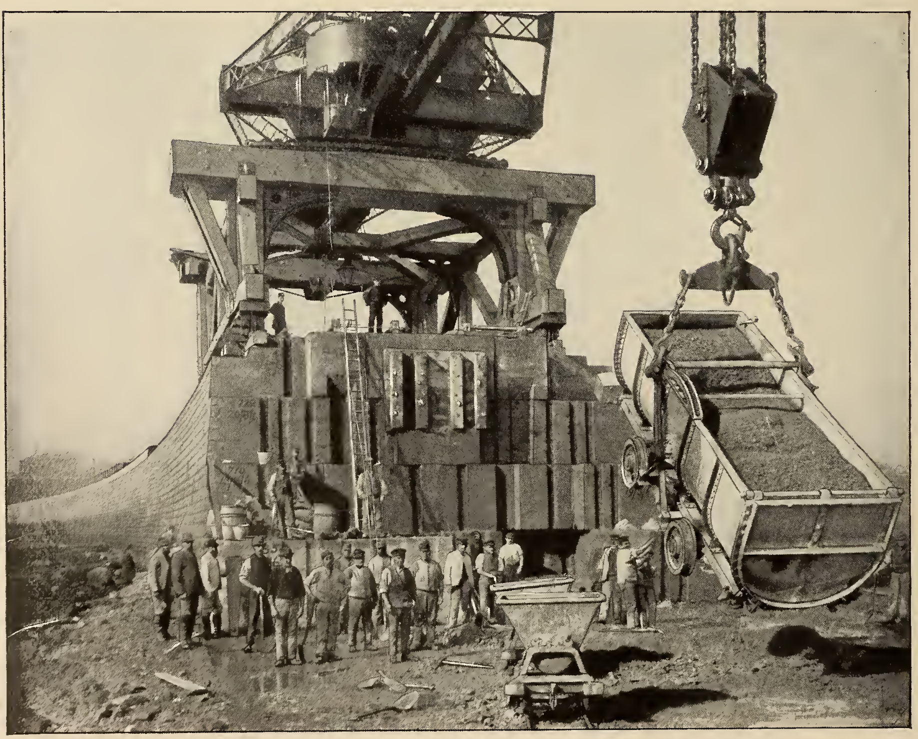
The stability of the superstructure is thus designed for all loads, as well as for no load, notwithstanding the effect of the ballast in the rear. It follows that the diameter of the live ring of rollers must be large, so that in a Titan of narrow gauge the ring will have to

overhang the sides to a considerable extent. The most severe test of stability is that afforded by the sudden release of a heavy load, which causes a swinging backwards. The writer is not aware of any of these machines ever having overturned in consequence of want of stability.

The carrying and travelling of so great a mass is not the least difficult problem which has to be faced. The number of wheels is proportioned to the load, but with the very slow speeds employed, pressures of from 10 to 15 tons per wheel can be safely adopted. The number of wheels may range from eight to thirty-two in different machines. Four lines of rails are generally required for the heavier machines, being arranged in two parallel lines of narrow gauge.

The Peterhead Titan, constructed to the designs of Sir John Coode, is of this type. Four lines of rails were used for the Titan at Bilbao Harbour, just mentioned. The great machine at Leixses was carried on two tracks of two feet gauge and 26 feet between centres, and thirty-two wheels,—eight wheels in each of four groups. The necessity for the employment of a double track was forced upon engineers by experience of the difficulty of moving the heavy block-setters on single tracks. None of the earlier machines had these double sets of wheels, although the loads of the Tynemouth and Sunderland machines, constructed in the eighties, have been but slightly exceeded even yet.

On some Titans cast steel wheels are used; on others, cast iron centres, with steel tires. Wheels are in adjacent pairs, having their journals in separate bearings, or in a single casting. Bearings have been made solid and bushed, as well as divided with caps. Double bearings have been hinged or pivoted, the better to distribute the strains.



TIPPING A 2 -TON "JUMBO" OF CONCRETE FOR LEVELLING OF FOUNDATION OF THE SUNDERLAND, ENGLAND, HARBOUR WORKS

Much trouble has been experienced with rigid bearings due to their lack of adjustability to bad tracks. A Titan will not run properly on a bad track, and, unless the rails are well laid, its mass will bend them and cause yielding. Unless wheels are in absolute contact it is difficult to move a Titan.

In good practice the use of rigid bearings, therefore, has been abandoned in the heaviest machines, the bearings being now carried in spring axle boxes. The Tynemouth Mammoth, 1882, though a 40-ton machine, had no springs; one built in 1886 had volute springs. In one machine, the ordinary type of leaf spring, as used on rolling stock, has been employed for travelling wheels. Generally now the springs are of the volute form, retained in circular recesses cast in the pedestals, and fit freely over pins cast on the tops of the axle bearings. The latter are guided vertically by guiding strips entering vertical grooves in the horns of the pedestals. The employment of these spring bearings has rendered the movement of the most massive Titans easy by comparison with those having bearings rigidly fixed.

The driving of the travelling wheels of these machines is done through pitch chains and sprocket wheels. Bevel wheels have been tried, but not with the best success. The sprocket drive is amply powerful; there is no risk of distressing the framing adjacent to the bearings, or of breaking teeth or links, if suitably proportioned and well made. The sprocket wheels should be cast in steel, both to ensure strength and durability. The chain links should be stamped in dies in the smithy, drilled through a drilling templet, and the pins turned, which can be done cheaply in a stud lathe, and riveted over neatly.

The jib is now invariably formed of two booms, side by side. In one instance which the writer remembers, that of one of the earliest machines made, a single box girder was used for the jib. Then, of course, the jenny was traversed underneath it, running upon rails which rested upon short cross girders bolted under the jib. This was in the early days of Titan construction, and was adopted because the jib was not of the cantilever type, but was instead sustained by tie rods attached directly to it, so preventing the jenny from being run along above it. With this exception, the writer believes, all jibs are double, having their booms placed parallel with a clear way the whole of the distance between the truck frame and the extreme end of the radius.

The jenny, or block carriage, is traversed along on rails upon the booms, the chain and load depending between them. The booms of cantilever jibs are made sufficiently rigid in themselves to resist both vertical and lateral stresses. Those of the king post type, with tie rods, are made rigid by the method of attaching the tie rods, which is through stirrup brackets, built up of plate and angle. These embrace, and are bolted to, the outer faces of the booms, and the tie rods are attached to the upper horizontal portion of the stirrup, which is of a horseshoe form. The horizontal portion of the stirrup is elevated sufficiently above the booms to allow of the passage of the block carriage underneath.

In machines of this particular type there is no cross traverse movement to the jenny. This simply runs from end to end in one line. All side, or cross traverse, movements are obtained by the revolution of the jib. In the rigid machines, the jib is traversed by a cross travelling gantry on which a crab is carried. The cross gantry then travels lengthwise on the jib, and the crab traverses the gantry. Titans of the non-radiating type, with a cross traverse movement to the crab, are cheaper than radiating or revolving ones, and some engineers prefer them, using in that case a travelling steam crane or a derrick for setting the side work, while the Titan does that which is straightforward only.

The jib extends back well behind the rear end of the truck, because these machines are necessarily of the balance type, and the balance, which consists mainly of engines, boiler, and water tank, and extra kentledge, lies well back of the truck. Sand, concrete, cast iron,

and water have each been used as kentledge, or extra ballast.

A Titan used at the Port of Leixses, in Portugal, has the largest radius of any yet made, namely, 144 feet, for loads not exceeding 15 tons. The test load was 100 tons, and the working load about 50 tons at a radius of 95 feet. The ballast at the rear of this amounted to 80 tons, in addition to the weight of the engine and two boilers.

Though the cantilever girders which form the jib are unconnected along the entire length traversed by the jenny, they are rigidly united over the area which is above the truck. This is traversed by two or more main cross girders and by such secondary girders as are required for the attachment of the operating machinery. Similar girders are employed when the king post and tie rods are used to brace the jib.

Wind bracing, either in the form of girders or of tie rods, must be brought from wing brackets forming a portion of the main superstructure over the truck to the sides of the jib. If of the girder form, it is either solid plated or lattice braced.

The jib of a Titan is pivoted at the centre of the truck, the post being for guidance only, and not for sustaining leverage, as in the case of the posts of ordinary balance cranes. The jib revolves on rollers. If the machine is of the rotating type, there is a circular girder, identical in size and shape with that on the top of the truck, and the rollers, which are retained in live rings, are interposed between the two girders. If the machine works through a portion of a circle only, the rollers are few in number, and may then either be connected, or have no connection with one another through segmental rings. The rollers are usually of cast steel, and are turned conically, the apexes of the cones meeting in the centre of the pivot.

Rollers revolve on spindles in the live rings. There is no stress of moment on the spindles, the sole function of which is to maintain the rollers in their correct position radially and circumferentially, the stresses being on the roller surfaces. The spindles pass through the inner and outer rings, and the rollers run between the rings. At the opposite ends the spindles pass into a flanged circular casting which surrounds the pivot casting, double nuts within and without the flange maintaining the spindles correctly endwise. The spindles will average 1½ in. in diameter, and the rollers 8 to 12 inches. They are cored to about 1 in. or 1¼ in. in thickness.

In order to distribute the load of the superstructure, which amounts in some cases to from 200 to 300 tons, the rollers are numerous, and are placed very close together, or within two or three inches of one another. The top and bottom paths, between which the rollers run, are composed of circular segments of steel, or wrought iron, riveted to the circular girders, and turned in a pit lathe to correspond with the degree of coning imparted to the rollers.

In the case of roller paths for which the capacity of the pit lathe is not sufficient, and also for segmental paths, the following method is adopted:—Straight steel bars of rectangular section are taken, and a bevel is planed on them, corresponding with the coning of the roller path. Then the bars are taken to the boiler shop, heated in a reverberatory furnace, and bent around a curved iron templet on a levelling or bending block.

The rotation is accomplished through gearing. For operating through a part circle only a segment of teeth is required; for complete rotation a ring of teeth, bolted up in eight, ten, or a dozen segments, is employed. The ring is carried on the top of the truck, and the pinion shaft comes down through a bracket on the jib. The pitch of such rings will range from 3 inches to 4 inches, depending on radius and load of machine.

Respecting choice of the two types of jibs, the writer thinks that the cantilever will survive the other. The work is simplified in this, and the trouble of erecting is diminished. When the braced jib is used, the king and queen posts have to be built of steel plate and angle, and they have to be socketed in

castings, or riveted with angle brackets to the jib. They must be capped with strong castings to receive the turned pins which pass through the eyes of the tie rods. These castings have to be bored for the pins. Then there are the stirrups, built up of plate and angle, with the details of their attachment to the jib.

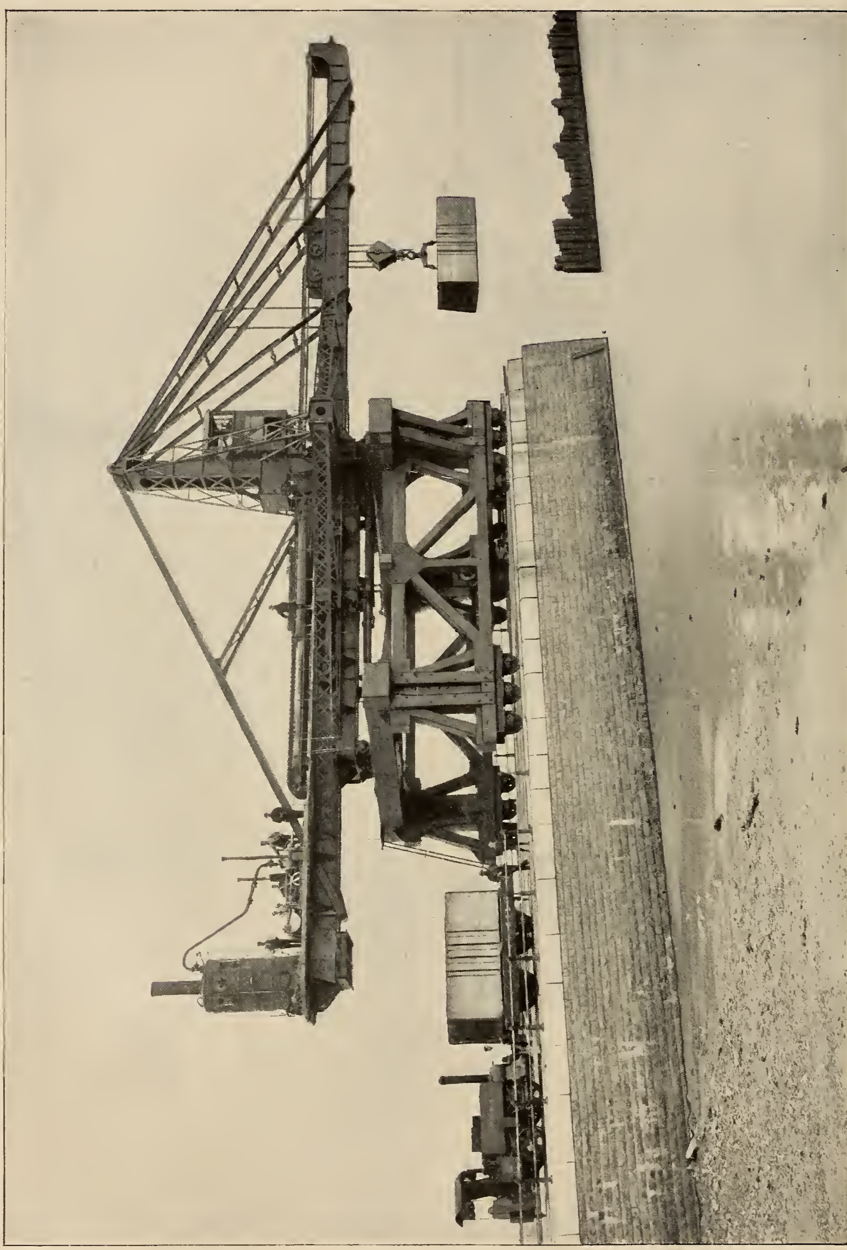
In a cantilever jib, on the contrary, all this is saved. But as a set-off, such a jib is more costly than a plain parallel one, and the weight of the overhanging portion is greater, when made solid plated, as they often are. The solid plating offers a larger area for wind pressure, which is objectionable, because Titans are always placed in exposed situations, and not infrequently suffer damage for this reason; in two or three cases, in fact, they have been totally destroyed. A carefully calculated system of bracing obviates some of this evil, and then, constructed thus, the lattice cantilever is preferable to the parallel jib with tie rods. A composite type of jib girder has been employed, plated over the portion above the truck, and of the lattice type elsewhere. This is the ideal form of jib.

The tie or truss rods are nearly invariably made of flat bars, because bars of that section will lie close together in their groups, and are, therefore, better adapted for this purpose than round bars would be. The width of the bar section is placed in the vertical plane. The tie rods fit with eyes over their turned pins, putting the eyes into direct tension, and the pins into double shear. At the jib end the bars are generally drawn down to a circular section, screwed, and secured with nuts. Special castings receive these, the castings being bolted against the plated work in the position required for the anchorage of the rods. Since so much depends upon them they are made of massive proportions. The writer has never known these cast iron anchorages to fail.

The making and fitting of the rods is not quite so simple a matter as it may appear to be. The rods are now generally made of steel, and the eyes are forged separately from the main bar lengths, thus necessitating welding. The latter is generally considered unreliable in steel, so much so that the American practice is to form the eyes of the rods of their pin-connected bridges by upsetting on the eye bars. There is so large a quantity of this special work done in the United States that elaborate plants have been constructed to perform this upsetting under great pressure, without injuring the fibres. But no such plant exists in Great Britain; and when a few years ago the eye bars of the Clarence bridge at Cardiff, which is pin-connected, had to be upset, they were sent to the United States to be done.

The practice adopted in a crane shop is as follows:—For the eyes, solid flat bars are taken, of the thickness required, of the maximum width, and long enough to permit of drawing down and welding. The end is drawn down and scarfed. The outer end, which has to be convex, is trimmed roughly to shape with a hot set. The hole is punched out under the steam hammer, about half an inch smaller in diameter than the finished bore,—the eye resting upon a bolster. If a large number of eyes are required, finish is imparted at a final heat in a die or stamp under the hammer. The eyes then, previous to welding, go into the machine shop to have the holes bored out to finished dimensions. A pile of them, say, half a dozen at a time, the number depending on the vertical traverse of the drill spindle, is clamped upon the table of a drilling machine. A flat cutter is inserted in a boring spindle, the lower end of which passes through a hole in the table, and the eyes are bored at a single traverse. Afterwards they are welded to the main bars.

It sometimes happens that a weld has to be severed, and another made, because the length of the bar is incorrect. It is not judicious to take these dimensions from drawings absolutely, but the length of each bar should be checked by actual measurement on the work, using a steel tape or a straining line. Then, with a slight possible adjustment



A 60-TON HYDRAULIC CRANE, SHOWING A 45-TON BLOCK SUSPENDED

on the screwed ends, there is no risk of having to do the work over again.

As regards the welding, no actual difficulty occurs in practice, provided a sufficiently mild quality of steel be used. Very rarely have welds been known to fail. There is no special art in making them sound. Scarf joints of about 6 inches in length, sufficiently upset, a suitable heat, the use of sand, and the services of three or four strikers at the critical moment, — these have been found sufficient.

In block-setting Titans the load is generally lifted and traversed by a jenny, or block carriage, running on steel wheels, or steel-tired wheels. In one machine, two jennys have been used, to be coupled together for lifting a heavy concrete block, or to be used separately when lifting a truck of rubble, the truck being supported at one end from one jenny, while the other end is lowered for tipping by the other jenny.

The engines do not, of course, like those of most steam crabs, travel with the block carriage. They are fixed at the back end of the machine behind the rear of the truck. Steam power is almost invariably employed, as being, on the whole, the most convenient. The location of the engines at the rear diminishes the amount of dead load to be traversed; there is the further advantage that, with the gearing and boiler, they assist very materially in counterbalancing the weight due to the overhang of the jib and its load. The aim in modern types is to so arrange parts as to throw all the weight possible behind the truck, the boiler hindermost of all.

The radial traverse of the jenny has been effected in different ways In some of the earliest machines the driving took place from the engines through a square gantry-shaft and bevel gearing to a crab, the gantry-shaft running alongside, and above the jib, similarly to those of ordinary square shaft traveling cranes and some goliaths. A sleeve bevel wheel then, which formed a portion of the crab, and sliding along the shaft, imparted motion through another bevel to the crab and its gearing. Tumbler brackets supported the shaft at intervals.

That practice is not followed now, but a jenny is used, and its radial or racking movement is accomplished through a wire rope and a special drum. The hoisting and lowering are done through another wire rope on its drum, while the slewing is effected through a set of gearing suitably arranged. Particular arrangements of gearing will, of course, differ in different machines, but the foregoing methods apply generally in most cases. Brakes are applied to each motion. A safety brake is necessary on the slewing gear of a Titan, not only for the purpose of arresting the momentum of the heavy superstructure at any required point without straining the toothed gearing unduly, but also to prevent rotation due to strong wind pressure. The various motions are put in and out by means of clutches, which are either of the cone or of the claw type.

There is nothing special to note about the bearings or gears, except that the latter are properly half-shrouded. The largest spur wheels are those used for hoisting. These are keyed directly upon the drum, so relieving the shafts of much torsional stress, and making a stiffer job. In a few cases a single spur wheel has been used; in most instances one is keyed on each end of the drum, the idea being to equalise the work and conduce to smoothness of running. Three keys are properly used, and the keying is done in such a way that the teeth of the pair of wheels come alternately, or "hit and miss."

The winding drums must be large in diameter,—from 3 to 6 feet,—to take a considerable length of winding rope for radial travel of the jenny, and for depth of deposition. They are invariably made with grooves for the rope to lie in as it winds up. There are two sets of spirals, right and left handed, so that the rope leads off from two points, winding up towards the centre of the drum. The grooves are either cast or cut.

In all the early machines chains were

A REVOLVING TITAN BUILT FOR THE MADRAS HARBOUR WORKS BY MESSRS. RANSOMES & RAPIER, LONDON

employed, but they were so clumsy and heavy that they have been generally discarded. Their weight caused them to sag about the centre when the carriage was racked out to a considerable radius, and chain rollers, or porters, were required to sustain them. In order, further, to permit of the passing-by of the carriage, it was necessary to make provision for throwing back the chain supports during the passing of the carriage, and also for their automatic return by counterweights behind the carriage. This involved the use of clumsy brackets on the flanks of the jib to carry the tumbler gear, so adding to dead weight and expense.

In one case a lighter arrangement was devised,—that of a system of traveling rollers to carry the chain and prevent it from sagging. The rollers were made to follow the jenny in each direction of its radial movements by means of light chain attachments. All these devices, which were both heavy and costly, are now rendered unnecessary by the use of wire rope.

The hoisting ropes are anchored both on the drum at one end and at the end of the jib on the other, and pass over the pulleys on the block carriage downwards and around the pulleys in the snatch block below. The latter is furnished with a beam instead of a hook, to receive the bars which are used in depositing the concrete blocks. Since the loads are so heavy, provision has to be made for lessening friction when slewing the beam for the adjustment of blocks in position. This is done by means of conical rollers, or of ball bearings, and frequently worm operating gear is added for easy and exact adjustment of the block.

Finally, the engines by which the motions of these machines are driven appear rather insignificant in comparison with the work which they have to do. They are in pairs, ranging between about 8 and 12 inches bore only, and worked with not more than 70 or 80 pounds of steam. These are amply sufficient for their work, and the reason of the apparent anomaly lies in the slowness of all the movements which they actuate, and the enormous leverage obtained by the trains of gearing. Two speeds of lifting are usually provided for, but lifting, slewing, racking, or traveling are not so rapid as they might be, even with the engines provided.

Block-setting is not like coal whipping, or unloading or loading general cargo. Stability and ample power are of far greater value. The test loads of Titans have varied from 25 per cent. above the maximum load to 100 per cent., the latter being a very extreme case, approached in only one or two cases. The first is quite sufficient. Under the test load a well-constructed Titan will do its work with as great ease as under its maximum working load.

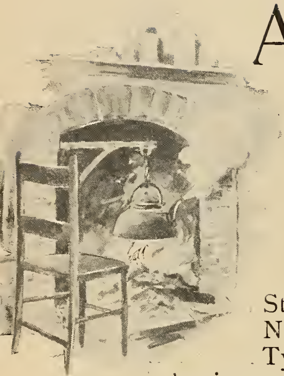
Since such machines must be taken apart and shipped in sections, it is impossible to rivet them up throughout. But certain sections must be united with bolts temporarily for testing. Not all the holes are filled with bolts, but bolts and tightly fitting drifts are inserted in alternate ones. In the parts subject to little stress the unfilled holes and drifts may exceed the bolts in number; in vital sections, subject to excessive leverage, the reverse conditions of things should exist.

The boilers employed are mostly of the vertical type. Boilers of the semi-portable multitubular type, and marine return-tube boilers have, however, also been employed. These are fed from water tanks slung underneath the jib girders at the rear, and arranged to clear the truck framing during slewing. The water is pumped into the boiler above with a donkey pump. The water tanks serve as a balance to the jib and load, and as such they are assisted by the engine, boiler, and the gearing adjacent to the engine. It is necessary to keep the tanks full of water, lest the balance should be disturbed, and there the use of sand, or concrete ballast, is advantageous, because its mass is constant.

A Titan may cost anything between £4000 and £10,000, according to design and dimensions.

AN EARLY LOCOMOTIVE

By W. D. Wansbrough



A LITTLE more than sixty years ago a thin quarto volume was published, entitled "A Description of the Patent Locomotive Steam Engine of Messrs. Robert Stephenson & Co., Newcastle-upon-Tyne."* In view of the interest which now, perhaps more than at any other period in the history of railways, attaches to these old-time locomotives, it may not be inopportune to bring to the light of day, in the pages of CASSIER'S MAGAZINE, the features of this relic of two generations ago.

Written "under the direction and revision of Robert Stephenson, Esq.," by Mr. W. P. Marshall, it is very plain to see, by the care bestowed upon the descriptive matter, and the really beautiful engravings (the plates reproduced in fac-simile in these pages are nearly two feet long in the original), that the importance of the subject was felt to fully warrant more than usual elaboration in the form and substance of the description. However this may be, it is tolerably certain that no single locomotive engine, before or since, has been distinguished by so complete and handsome a record.

This engine was a development of the famous *Patentee*, of 1834, which was the prototype of all six-wheeled, single-driver passenger engines. It will be noticed that the tires of the driving-wheels are without flanges, in accordance with Stephenson's patent of 1833, which provided that, to allow of the easier passage of curves, the middle pair of wheels of six-wheeled locomotives should be made without flanges, and cylindrical instead of conical in form. The inside and outside framing, and, indeed, all the details of this early model are deserving of close attention.

With becoming modesty, yet with an underlying consciousness that the stage of finality in locomotive construction has at length been reached, the author of this volume affirms that "the construction of these engines has undergone very great and extensive improvement during the last few years, and they have not long arrived at their present state of perfection; those made before the last ten years were greatly inferior, having not more than a fourteenth of the power of the present ones.

"The engine was made in 1836 for Messrs. Cubitt, the contractors for constructing a part of the London and Birmingham Railway near Berkhampstead, and was used by them for carrying the earth excavated in the construction of the line. The engine was employed in this manner for about a year and a half, when, the works being nearly completed, it was no longer required, and was purchased by the railway company for the purpose of carrying ballast for repairing the road and other similar purposes, in which work it is now employed, together with other engines.

"Fig. 1 is a side elevation of the engine and tender. The engraving is highly shaded to show more fully their general appearance.

"Fig. 2 is a longitudinal section through the centre of the engine and tender showing their internal construction, the section below the boiler being taken through the right-hand cylinder and crank.

"Fig. 3 is a plan of the engine and tender. The plan of the engine is

* London: John Weale' 1838.

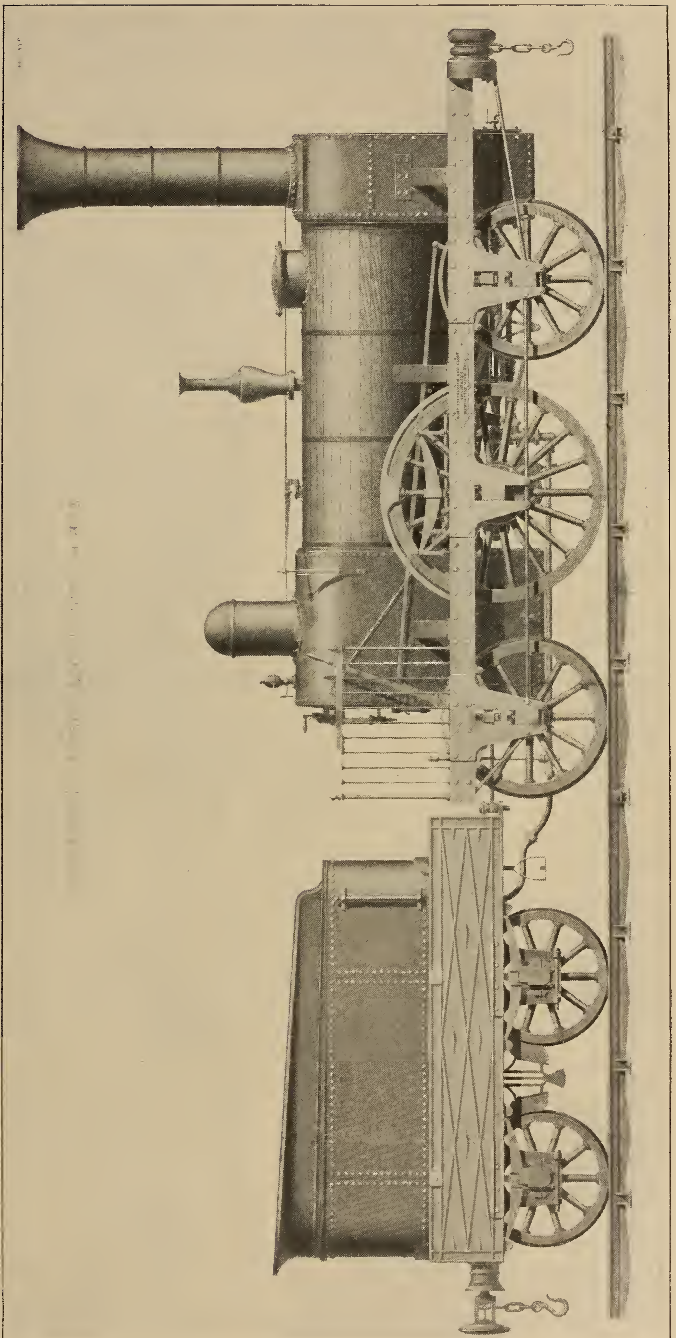


FIG. 1.—A SIDE ELEVATION OF STEPHENSON'S LOCOMOTIVE OF 1836

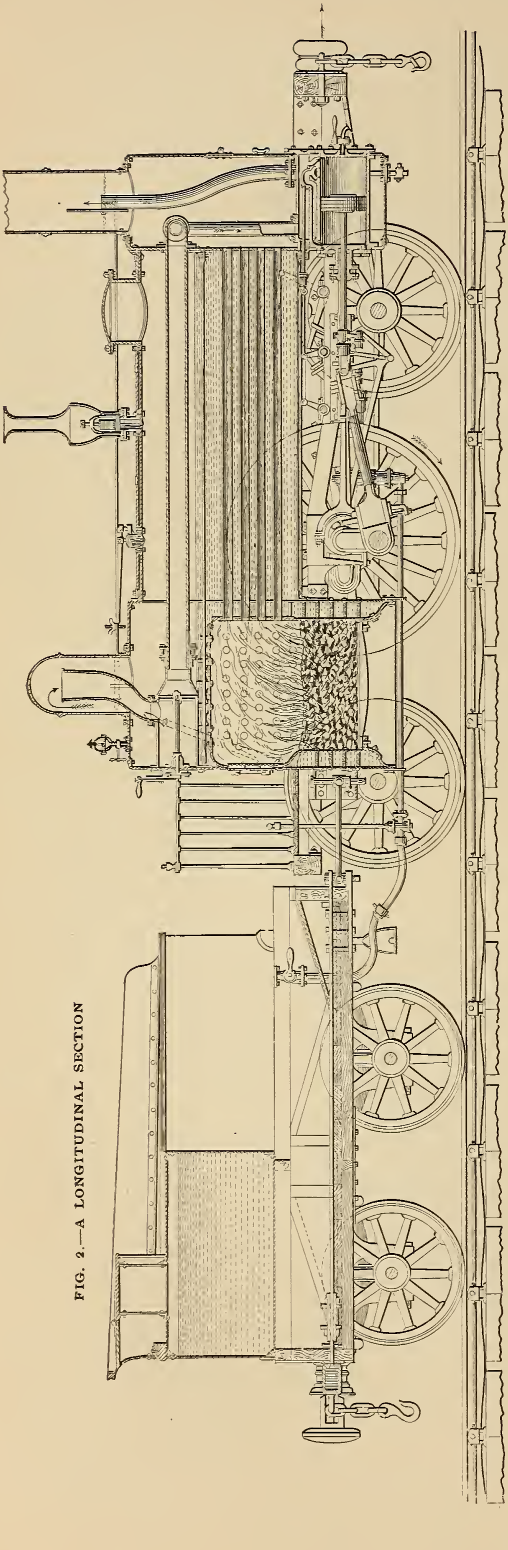


FIG. 2.—A LONGITUDINAL SECTION

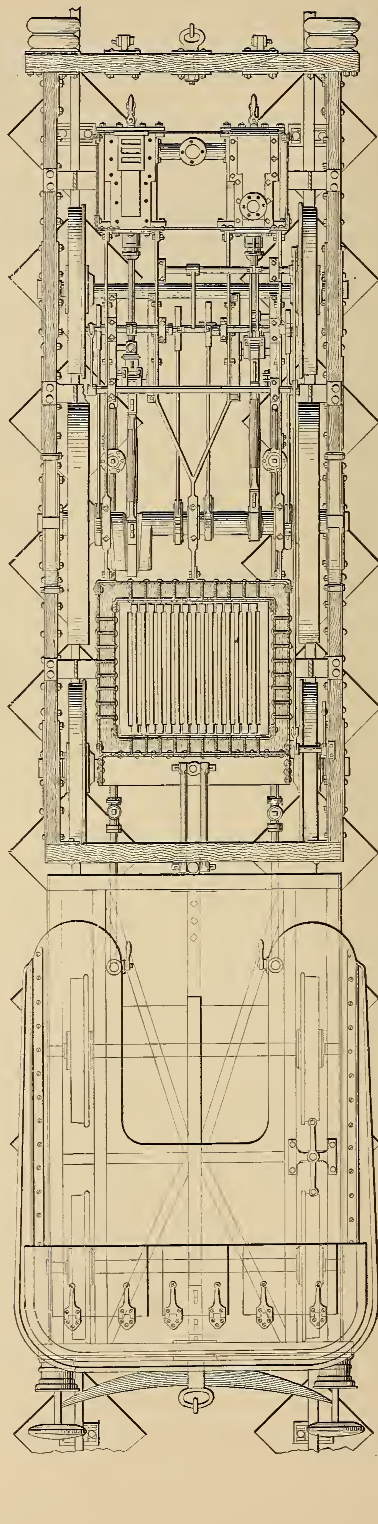


FIG. 3.—A PLAN OF THE ENGINE AND TENDER

taken just below the boiler in order to show the machinery beneath it, and at the left cylinder the plan is taken a little lower down, showing a section of the steam chest and more of the machinery. The plan of the tender is taken at the top."

The diagonally placed stone sleepers upon which the fish-bellied rails are laid should be noticed.

"Figs. 4 and 5 represent an elevation of each end of the engine, and a cross section through each of the end portions.

"The plates (in the original) are all drawn to a scale of three-quarters of an inch to a foot, or one-sixteenth of the real size, and the same letters of reference are used to denote the same parts in each of the figures."

We cannot follow the author through the 67 quarto pages in which every detail of the "patent locomotive steam engine" is conscientiously set forth. The text is embellished with numerous wood-cuts illustrating the detail parts, but the plates which alone are reproduced here in part are amply sufficient for our present purpose,—a rapid survey of the principal points of the engine.

The boiler-barrel was 7 ft., 6 in. long, by 3 ft., 6 in. diameter outside, made of wrought iron plates 5-16 in. thick, lap-jointed. The rivets were ⅞ in. diameter at a pitch of 1¾ in. The barrel was lagged with wood, and this was secured by iron hoops. The external firebox was 4 ft. wide and 3 ft., 7½ in. long, extending 2 ft., 1 in. below the barrel, and, like it, was composed of 5-16-in. plates.

The flanging of the plates of the inner firebox in Fig. 2 should be particularly noticed. It is of copper, 7-16 in. thick, except where, to receive the tubes, the thickness is increased to ⅞ in. The firebox stay-bolts are of copper, ¾ in. in diameter, at 4 in. pitch, the roof being sustained by six roof bars. These bars are thickened at the bolt-holes, and cut away on the under side, so as to touch the roof-plate only where the bolts pass through, the latter being secured by nuts screwed on at the under side of the crown-plate. There is a lead rivet to act as a fusible plug. Our author mentions, in passing, that "wrought-iron fireboxes cost considerably less than copper, but are liable to crack and become leaky at the joints."

There were 124 brass tubes, 1⅝ in. in external diameter, "made of best rolled brass one-thirteenth of an inch thick (called No. 13 wire gauge); the edges of the brass are properly chamfered and lapped over each other and soldered together, the solder being applied inside; the tubes are then drawn through a circular steel die to make them truly cylindrical." The tubes fitted plain holes in the tube-plates, and were ferruled at each end by a slightly conical steel ring. A foot note states:—

"It appears that the merit of the first invention of a boiler with tubes is due to a French engineer, M. Seguin, who had a patent for it in 1828, although the application of the principle in the *Rocket* engine was undoubtedly an independent invention. Brass tubes were first tried in the locomotives on the Liverpool and Manchester Railway, in 1833, at the suggestion of Mr. Dixon, the resident engineer, and were found to be very much superior. They are now universally used for locomotives. They last about two years, and lose about 6½ pounds in the time they are in use. They cost about £1 each."

The boiler was strengthened by six longitudinal wrought iron stays, with jaws and pins at each end fitting "a piece of wrought-iron, called T-iron," rivetted on each of the end plates. The smokebox is 4 feet wide and 2 feet long, the tube-plate being ½-in., the remainder ¼-in. plate. The chimney is 15 in. in diameter; "its height is obliged to be small."

"The waste steam rushes with great force out of the blast-pipe made of copper ⅛ in. thick and 3¾ in. in diameter inside at the bottom, tapering to 2½ in. at the top) up the chimney, carrying the air with it, and causing a very powerful draught through the tubes and the fire; a whole cylinderful of steam is let out at each stroke, and the two cylinders deliver their waste steam alternately, so that, when the engine is running fast, an

almost constant current of steam in the chimney is produced, and the interval between the blasts can scarcely be perceived. By this method the fire is not blown, as is usual, by forcing air into it, but by extracting air from the flues and drawing air through the fire. * * *

" There is, however, a considerable loss of power attending the use of the blast pipe, from the obstruction it causes to the egress of the waste steam. In a locomotive engine its average resistance is not less than 6 pounds on the square inch; and when running very fast and the issue of waste steam is almost continuous, the whole loss of power amounts to nearly half that of the engine."

The spring balance safety valve, having a leverage of 12 to 1, allowed the pressure to accumulate sometimes to 10 pounds above the working pressure of 50 pounds, and, as the author remarks, the safety valve is but an imperfect means of ascertaining the pressure of the steam in the boiler.

" In stationary engines, which are generally worked at a much lower pressure, a mercurial gauge is often used to indicate the pressure of the steam; but this instrument cannot be used in a locomotive, as a tube of great size and not less than 12 ft. high would be required. It has, however, been used as a means of testing the accuracy of the indications of the safety valve by a temporary connection with the engine."

The boiler is, as will be seen, also fitted with a separate lock-up, direct-loaded safety valve; with glass water gauge and two gauge cocks; with manhole and mudholes; with two blow-off cocks, worked from the foot-plate, and with a steam whistle, " which is very effective, and its sound can be heard at a great distance.

" The area of the fire grate is 9½ square feet. It is 18 in. below the bottom of the lowest tubes, and the space for the fire, when quite filled up to the tubes, is 14 cubic feet, and holds about 2½ cwt. of coke; but the firebox is not always so full as this, and usually contains about one and a half or two cwt.

" The surface of water exposed to the heat directly radiated from the fire is the whole surface of the internal firebox, deducting the fire door and the tubes, and is equal to 50 square feet, and that exposed to the current of hot air, or conducted heat, is the interior surface of the tubes, and is equal to 432 square feet. The surface exposed to radiated heat is considerably more efficacious in generating steam than that exposed to conducted heat only, as the supply of heat is more copious, and the proportion was found to be about three times in an experiment tried by Mr. Stephenson. * * *

" The area of passage for the heated air from the firebox to the chimney is the sectional area of all the tubes inside the ferrules * * * equal to 1.06 square feet. The area of the passage through the chimney is rather more, or 1.23 feet. The steam room in this engine is generally about 44 cubic feet, and there is no perceptible priming under ordinary circumstances."

It is incidentally mentioned that in the first engines the copper steam pipes were brought straight down to the cylinders across the ends of the tubes, but they were found to be very rapidly destroyed by the hot air issuing from the tubes, " which is nearly hot enough to melt copper."

The cylinders were 12 in. in diameter and of 18-in. stroke, the steam ports 8 in. by 1 in., and the exhaust port 8 in. by 1½ in. The lap of the slide valves was only 1-16 in., and it seems quite clear that its only object was to prevent both steam ports from being open at the same time. The advantages of lead were, however, recognised, as the steam port was opened for the next stroke just before the piston reached the end of the cylinder, " in order to bring it up gradually to a stop, and diminish the violent jerk that is caused by the motion being changed."

It is worthy of remark, in passing, that in the year 1836 the word " travel " was used in a different sense from the present accepted meaning of the term; for, in order to keep the steam on the piston as long as possible, the valve moved nearly ½ in. beyond the port at

each end, or "over-opened," as we should say. It is specially mentioned that "this distance that the slide moves beyond the port is called the travel."

The author also mentions, almost apologetically, that the total power is diminished a little on account of the steam being shut off before the end of the piston's stroke, "the extent of this action being, however, very limited, as the piston is less than ¼ in. from the end of its stroke when the steam is shut off."

It is somewhat strange that the writer, and more so that the eminent reviser of this description, after so minutely detailing the many and obvious disadvantages entailed by keeping on the steam during what was practically the whole stroke of the piston, should, in his very next paragraph, disclose the remedy, but apparently without any real knowledge of the importance of his casual remark that "in stationary and marine condensing engines the steam has usually very little or no lead, but it is shut off at two-thirds or three-quarters of the stroke, giving a great amount of expansive action; and the eduction has a great deal of lead, the port being nearly full open at the commencement of each stroke."

Had these conditions been fulfilled in the engine before us, or, in other words, had lap been added to the slide valves, a very much better result would have been attained. It is evident from the description that the principal object of the designer of this engine was to get as much steam into the cylinder as possible, leaving its egress to take care of itself, with the result, of course, that the cylinder became choked or gorged with steam, which at anything above a very slow speed had to be actually forced or propelled out by the piston.

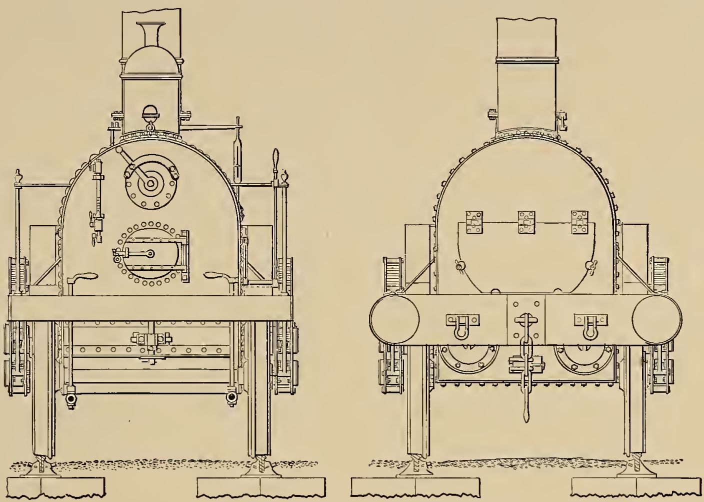


FIG 4.—BACK AND FRONT ELEVATIONS

It is not at all improbable that the wheels would have revolved more quickly had the cylinder-cocks been kept fully open to relieve the congestion. The consumption of fuel in proportion to the actual work done must have been enormous under these conditions, particularly as the gab-motion with which this engine was fitted afforded no means of shortening the stroke of the valve so as to work with some degree of expansion. The combined reversing and expansion gear formed by the Stephenson-Howe link-motion was not introduced till 1843. As a matter of fact, the negative or back-pressure in this engine "amounted to 30 or 40 per cent. of the positive pressure of the steam upon the piston when the engine is running very fast,

and the power of the engine is diminished nearly one-half."

Many pages are taken up by an exhaustive description of the slide valves and the singularly intricate valve gear by which these remarkable results are achieved, the writer's enthusiasm leading him finally to proclaim that "the great perfection of the present locomotives, and their superiority to the old ones, is caused not so much by the application of new inventions to them as by the combination of many former ones, and the uniting together several plans which, separately, would be but of small value."

With these evidences of superiority before us it is saddening to reflect upon the probable condition of affairs prevailing in the cylinders of "the old ones."

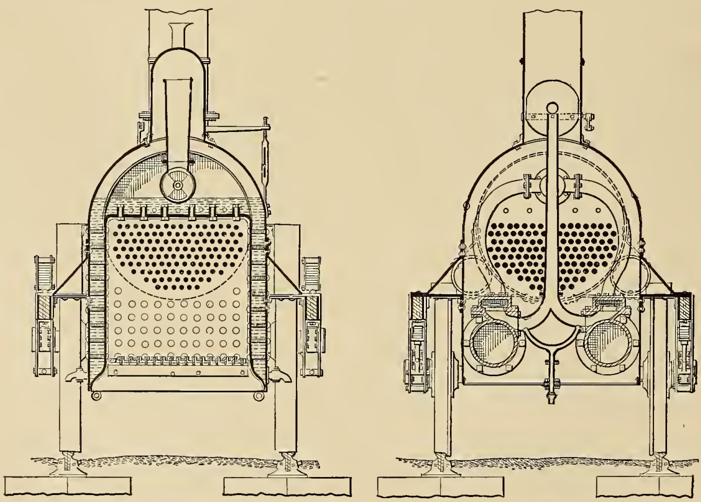
But we must hasten to conclude our running survey by some mention of the recorded performance of this engine. The driving wheels being 5 feet in diameter, the tractive force would be

$$T = \frac{12^2 \times 18}{60} = 43.2 \text{ pounds for each}$$

pound of effective pressure upon the pistons.

The author states that this engine "has drawn a load up an inclined plane that was equivalent to 220 tons gross weight upon a level (including engine and tender) at a velocity of 14 miles an hour, which appears to be about the extent of the power of the engine, with the steam at the usual pressure of 50 pounds per square inch in the boiler." Taking these figures, and using D. K. Clark's formula for the resistance, of $\frac{V^2}{171} + 8$, we find that about 46½ pounds net effective pressure must have been maintained in the cylinders.

The distance traversed under these conditions is not stated, and there is some reason to doubt whether the actual efficiency of the engine at all times came quite up to the figures quoted by the author. However this may be (and it would be ungrateful to criticise too closely), we cannot refuse our assent to his concluding paragraph, which remains as undeniably true now as when it was written sixty years ago, that the "great power and velocity of the present locomotives could not have been obtained without the rapid means of generating steam afforded by the use of the tubes; and the tubes would have been useless without the powerful draught produced by the blast, which



SECTION OF FIREBOX SECTION OF SMOKEBOX

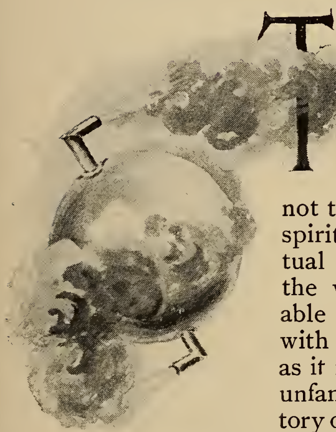
FIG. 5.—CROSS SECTIONS OF THE END PORTIONS

increases in intensity with the velocity and with the necessity for increased action."

Ludicrous though this little engine (notwithstanding its "great power and velocity") would appear, standing buffer to buffer with our *Greater Britain* or *Dunalastair* of the present day, it is impossible to avoid the conviction that, with the important exception of the method of working the steam expansively, we have added little to the governing principles of locomotive construction through the long interval which separates us from this early model.

ARISTOTLE AND MODERN ENGINEERING

By Dr. Robert H. Thurston



THE proposition that modern engineering, and all our marvellous progress in the material, not to say, also, in the spiritual and intellectual development of the world, are traceable to their origin with Aristotle, strange as it may seem to one unfamiliar with the history of those evolutions which are, historically, vastly more interesting, and intrinsically enormously more important, than the political events which constitute the main stock in trade of the average historian, is none the less a truth of very literal accuracy. Called upon, recently, at short notice, to address the graduate students at Cornell University, this thought occurred to me as worthy of development, and it is here presented as possibly interesting to others, and in a somewhat more finished form than was given its first crude development in a brief, extemporaneous address.

This thesis, which, it will perhaps be presently agreed, may be successfully sustained, is the following:—Aristotle introduced the scientific logic, founded the earliest school of scientific investigation and experimental research, and brought about the foundation of the first —perhaps it would be right to even assert, the only—real university, in the true sense of that word, with which history acquaints us. Aristotelian method founded the physical sciences and gave them their earliest stable form. The natural sciences, once established as to fact and as to method, on the Nile, found safety among the Saracens during the Dark Ages and were then imported into Europe after centuries of repression.

Science, pure and applied, about the beginning of the sixteenth century, began to attract the attention and to engage the highest powers of the ablest intellects of the time. Applied science took, gradually, a higher and a more important position among the modern departments of learning, and upon it came to be finally based the progress of all the arts and applied sciences of industry. Experimental research became an adjunct of, a partner with, invention, and all great advances in wealth and all material progress came to be due to scientific labours and scientific method.

With growth in wealth, and with more general diffusion of comforts, luxuries, education and learning, came opportunity for mental development, and moral, intellectual and spiritual progress. Aristotle, by his noble genius, was inspired with a new

thought, founded new methods, set up new schools, gave stimulus and impetus to the arts and sciences in their infancy, and brought about all those great changes which make, to-day, our pride and our boast, and our best support in life. And thus his successors, the inventors, the mechanics, the engineers of our day, who necessarily are, in this time and in this field, his direct progeny and representatives, owe to Aristotle, as does the world no less, the foundations of their highest honours, and to him are due their most grateful acknowledgments. A study of details, however, will still be required to exhibit the truth of the thesis clearly.

The learned professions claim, each, a more ancient lineage than any other; but the earliest mechanics and the most modern of engineers, alike find ancestry in the prehistoric past. In those more discriminating times, so mythology tells us, the inventor, the mechanic, the engineer familiar with the constructive arts of peace and war, was deified; but, even if this be true, the days of the deification of the mechanic, engineer, and inventor have long since passed and are not likely soon to return; he must now content himself with, often, less than the consideration accorded to ordinary mortals.

Vulcan is supposed, by the engineer, to have been deified, in primitive times, for his services in providing a forge, with fire and lights, and especially for his success in introducing mechanical engineering, and in teaching Zeus methods of distributing electrical energy from Mount Olympus. Tubal Cain, who, in mythological times, made all manner of apparatus in brass and in iron, in the scriptural genealogy, became the father of the race of later practitioners in engineering. But the unbroken line of descent to be traced by us originates visibly at a later date.

Aristotle laid the foundations upon which the now great superstructure of modern engineering was built by Archimedes and Hero, and their successors, by Leonardo, Michael Angelo, and the men of science and the engineers of subsequent date, many of whom, like the last, were more honoured for oratory, or for their art-productions, than for the less interesting and entertaining, but yet more important, works built by them for the military and the industrial establishment.

The Persian conquest, and especially the Macedonian expedition into Egypt and its outcome, constitute what may be fairly claimed to be considered the most impressive events in all authentic history. It resulted in the reduction of a great empire to subjection by the Greeks; but it also ultimately resulted in the founding of a commercial emporium upon the banks of the Nile which rivalled, and, in the end by its competition, destroyed Athens and Greece.

Still more important were the results of this conquest, and of the deliberate founding of Alexandria by Ptolemy Philadelphus, in their influence upon the intellectual empire of the world. The building of Alexandria and the concentration at that point of an aristocracy, of wealth, and of physical and intellectual power, brought about the establishment of the Museum of Alexandria, the first true university that the world ever saw—perhaps it might be truthfully asserted, the only real university ever yet organised.

There, for the first time in history, was organised an institution in which were taught all the sciences, all the literatures, all the arts of the time. What university of to-day can claim to have attained, or even to have attempted, such universality of scholarship? With the foundation of this university, came the beginnings of scientific method and the laying of the foundations of modern engineering, and of our highest work in applied science and in the arts of construction and invention.

Aristotle, a pupil of Plato, imbued with much of the Socratic speculative idea, displayed the noblest type of genius by independently founding a new and a truer school of philosophy. Instead of evolving, out of his own inner consciousness, what ought to be, in nature as well as in morals and in logic, and thence reasoning out the probable —which usually proved untrue, once

nature was consulted as to fact—he rather sought out the facts, and reversed the Platonian process.

He thus founded the modern scientific method, and, collecting facts of observation, and studying phenomena by experimental investigations and formal and sometimes elaborate research, he was able to then determine the mutual relations of those facts and truths and thus to establish a law of science. His first efforts involved, necessarily, many errors; but the method was a permanent acquisition, and men of science pursue that method to-day. Its products are now to be found in every known field, and all the now familiar sciences are thus built up. It is by this system that they are continually growing by steady accretion of facts and by identification of new laws of nature.

With the application of the sciences in the useful arts have come all contemporary industrial processes. Those processes constitute the methods of applied science in modern engineering, and these, in turn, are the immediate sources of the wealth, the comfort, the luxury of the people, and the basis of all success in education; these constitute the necessary material support of good morals, intelligence, and enlightenment.

Aristotle's most distinguished pupil was Alexander himself, and his influence over the monarch is known to have been extraordinary. The royal pupil favoured the philosopher as never emperor favoured the most politic of courtiers. He gave him a staff, when accompanying the expedition into Asia, which was almost an army in itself. It is sometimes stated that a vast sum of money and thousands of men were set apart in the prosecution of this greatest, if not actually first, of scientific exploring expeditions.

Notwithstanding all his faults, and in spite of the enormity of his crimes, to Alexander the Great must be accorded high honour as the first and greatest patron of real learning. It is to him that we owe the existence of Aristotle's greatest works; it is to him that we must ascribe the credit of making it possible that the works of Aristotle should exert their unmeasured influence upon all later times, and among all learned men of all nations. To him is due the founding of the greatest of universities, the advancement and the continued life of science and of scientific philosophy, the Saracenic civilisation, the sciences and the applied sciences, the arts and engineering of modern times.

With the death of Alexander, the irresistible will of Ptolemy, exerted in accordance with the views of Aristotle, carried on the work and made the organisation of the Alexandrian university and the establishment of the Aristotelian method safe, and insured their fruitfulness for centuries, until the loss of no one division of the intellectual world could affect the permanence of Aristotle's inconceivably magnificent and productive work.

Twenty-two centuries ago, the death of Alexander and the breaking up of his empire left the provinces of the Nile in the hands of Ptolemy Soter, and, what is none the less important, made that great soldier, statesman and philosopher the head of the Egyptian Church as well as of the government. This gave him absolute control of a rich and prosperous, and, for the time, highly civilised nation. Into the midst of an already advanced civilisation he imported the whole Greek system of social and industrial knowledge and life.

Alexandria promptly became the centre of the highest social life that the riches, material and intellectual, of the whole world could sustain. To insure and sustain, to permanently establish the reign of the Ptolemies,—a problem of no little difficulty and one involving great risks and uncertainties in such a situation, — the reigning monarch adopted every possible expedient, including provision for the organisation of learning and the union of all learned men in one great university and for one great and acceptable purpose.

The Alexandrian "museum," actually the University of Alexandria, was founded as the nucleus of education and

philosophy, the fountain of intellectual light, the foundation of an intellectual and moral empire. It was intended to afford to its pupils instruction in every philosophy, in all the sciences, in every known literature, and in all the arts of the period. It was liberally endowed and magnificently sustained, and the wisdom of its founder was fully justified by the results of its work. The sages of all nations flocked to this magnetic centre of learning, and the physical sciences had here their birth, and philosophers and literateurs found here their home.

The army of men of science, engineers and philosophers, brought out of Greece by Aristotle and Alexander, furnished ample store of science and intellect upon which to draw in the organisation of the great university, and there was no difficulty in securing representation of all the arts, all the sciences and all the literatures of the time. A few generations sufficed to produce wonderful advances in every field, and the rich collections of those days at Alexandria were a reservoir of learning for generations.

Especially did the philosophy of Aristotle here find fruitage in the development of the natural sciences and of the applied sciences of engineering. Among the most justly famed men, who at one or another period, lived and worked in this grand and catholic institution, were Euclid, whose geometry, now, two thousand years later, still has its place in our curricula of the schools; Phalareus, the founder of the great library of, as is reported, 700,000 volumes; Eratosthenes, the astronomer; Hipparchus, no less famous, and Ptolemy, Hypatia and Cleon, with unnumbered other minds of surpassing genius. Nor were tools wanting. The physicist, chemist, astronomer, mechanician, engineer, found equipments of apparatus as complete, for the time, and as perfect, as power and wealth could provide. Experimental research was encouraged, and those records which are now extant,—a small proportion of all published in their day,—undoubtedly, show clearly that science was no less active, ambitious and successful in research then than now.

The Macedonian campaign had demanded the employment of an enormous amount of scientific, and especially engineering, talent, and the scientific campaign of Aristotle, which accompanied that of the emperor, reinforced splendidly this mighty intellectual force. With the foundation and upbuilding of Alexandria all this talent found expression, first in the work of planning and construction of the new capitol and new university, then, for generations, in prosecuting the work of the scholar and the investigator, in the pursuit of scientific and philosophical studies and in engineering construction or research, in mechanical invention or production. While the philosophers were disputing over the speculations of their predecessors and contemporaries with misty and profitless phrases, Archimedes, Hero, and others were building the foundations of modern engineering, and were preparing the way for the application of scientific knowledge and of the natural forces in all industries. Men of words abounded then, as always; but men of deeds, the ants and the bees of every civilisation, were accomplishing great works, for their own and for all future generations.

Archimedes, mathematician, astronomer, physicist, engineer, compelled all later generations to give him honour as the discoverer of the geometrical relations of the sphere and the cylinder, of approximate quadrature of the circle, the exact quadrature of the parabola, and his determination of the solution of the problem of the alloy. As mechanician, he produced the correct theory of the lever, and invented no less than forty interesting devices, including the endless screw, the pump, the organ, and the "burning glass," with which latter novel weapon he is said to have set fire to the ships of an enemy's fleet from a considerable distance. The story is probably fabulous, but none the less interesting, as exhibiting the faith of the people in the man and as indicating the character of his pursuits.

As engineer, Archimedes was looked

upon as hardly less than a magician. He produced catapults which threw enormous stones and heavy pikes, at long range, into the ranks of the enemy or into his ships; and great derricks were built by him with which to lift the attacking craft out of water or to upset it, destroying all on board. His proposed use of the lever meant the production of then inconceivable inventions in machinery and engineering construction, and his own estimate of its importance was expressed by the familiar quotation, "Give me whereon to stand and I will lift the earth." Archimedes was the first, and perhaps the most inventive and greatest, of early engineers. His lever still moves the world, and his spirit is inherited by generations of the men who have made modern civilisation possible.

Hero was the most famous successor of Archimedes. His "Pneumatica" was published to the Alexandrian world after the death of Euclid and of Archimedes, and very likely includes inventions of the latter and of Ctesibus, for nothing is said to indicate what part of the collection of inventions there described is due to the author and what to earlier scientists and engineers. In this little volume, however, are contained descriptions of the germs of the "fire-engine," or steam-engine, of the Marquis of Worcester, of the steam-turbine, of the water-tube steam-boiler, of numerous steam and air fountains, and of many other curious and, undoubtedly, to the ancients, mysterious contrivances, not omitting the magician's marvellous bottle, the source of many wonders. He anticipates or supplies the germ of numbers of modern engineering apparatus and mechanisms.

In one of his "propositions" he shows how temple doors may be opened and closed by steam; in another, how birds shall be made to appear to sing; in another, he raises water in a fountain by fire; and in still another, he accomplishes the same thing by a "solar motor." Hero was the great mechanical engineer and scientific author of his time. Perhaps the most remarkable event in the history of the mechanic arts and of engineering is the revival of the steam-turbine in our own time as the rival of the modern steam-engine, which, with its complication of parts, its extraordinary perfection of structure and workmanship, and its summary of the inventions of the great engineers and mechanics of a century and more, has been considered to be the crowning effort of modern inventive and constructive genius. Two thousand years after Hero, the world now takes up his steam-engine, and its modern reinventors and improvers promise that, with this instrument of the old Greek times, they will revolutionise steam-engine construction, bringing about so complete a turn that the cycle shall take us back to the Alexandrian and his toy.

But the time of Hero was that of the commencement of the period of inevitable decay which history assures us must always succeed to such an epoch of genius and of rapid advance in civilisation. The Ptolemies passed away and the dusk of mediæval night came on. Euclid and Archimedes, Hero and Ptolemy, Hipparchus, and, finally, the unfortunate Hypatia, whose fate is told by Kingsley with such terrible vividness, all passed out of the precincts of the great university into the shades, and the ancient Greek intellectual life entered upon its period of old age, and not long after expired.

The Dark Ages of the dozen succeeding centuries reproduced no such men and no such intellectual life as had illuminated Athens and Alexandria in those early days. After Hypatia, came the Saracenic conquest, the destruction of the great university, and the destruction of the great libraries of the Museum and of the Serapion, with their three-quarters of a million volumes, written on parchment and on papyrus, the fruits of the labours of innumerable scribes and authors, for generations, throughout the world. This meant the extinction of the beacon-light of the world.

But while this great catastrophe put an end, for the time, to European sci-

entific and industrial progress, the fire of intellect remained alive here and there, and a spark was enkindled in the souls of the conquerors which presently flamed up, and, later, communicated itself to European thought once more. The Saracens gained a high degree of civilisation and of scientific achievement. For centuries, they kept knowledge, science, philosophy, alive until light began to break once more north of the Mediterranean sea. Then Arabic thought, Saracen letters and the mathematical and the physical sciences, including astronomy and chemistry, were imported into Italy, France, Great Britain and Germany with great rapidity.

The development of men of science, philosophers, physicists, mathematicians, astronomers and engineers out of the older Mohammedan devotees and warriors was a process of wonderfully interesting growth and evolution. Before the Arabs were finally driven out of conquered Spain, they had imported into that country the advances in science and in engineering of the intervening centuries; and they left there, at Cordova, in the Alhambra and elsewhere, evidences of their meteor-like intellectual progress. Modern European science grew from their planting.

In the interval of twenty centuries between the time of the steam-engine of Hero, revolving in the Serapion at Alexandria, and the time of Watt and the modern steam-giant, a few great men of science and a few mighty engineers appeared. Among the first to enlighten the world of Europe after the dawn following the night of the Dark Ages had begun to break, was Leonardo da Vinci, who, though a man of science, a warrior, and a learned and successful engineer, is to-day represented by biographical authorities mainly as an artist. An artist he was, and a noble painter; but, like almost all great artists, he was primarily a mechanic and engineer. The mechanic's intuitions and the mechanic's control of the brawn by the brain is essential to success in painting and sculpture, and the artist and the engineer are brothers.

Da Vinci learned mathematics from the Arabs as they had learned its elements from the Hindus; he absorbed from them the art of the chemist, and Greek fire, Arabian gunpowder, and Djarfar's acids were familiar to him; his writings and his works indicate that he was equally familiar with the philosophy of Averrhoes and of Aristotle, of whom that great Saracen was a disciple. His knowledge of the Saracenic science and arts made him familiar with their machinery of irrigation, their water-wheels and pumps, their cutlery, and especially sword-making, and their artillery.

Hallam says that " His knowledge was almost preternatural." His learning as a mechanic and as a mechanician included not only applied mechanics and the action of the lever, but the facts and primary laws of hydraulics, of acceleration and of impact, of the laws of ballistics and of gunnery, the construction of fortifications and the operation of machinery. His treatise on " Natural Philosophy and Mechanics " antedated that of Galileo.

Galileo led the way for Newton, and Newton founded the science of mechanics of our own time and gave to modern engineering its scientific foundation. At the commencement of the sixteenth century, Leonardo had built its lowest foundation upon a substratum of Greek and Arabic science, and at the commencement of the eighteenth century, the superstructure, now so familiar to us, had begun to rise into view.

The men of pure science were encouraged by the example of Leonardo in their earnest pursuit, and men of science sprang into prominence among warriors and monks, and began to assume that ascendancy which has never ceased since then to become continually more and more impressive. A little later, and, with further development of science and the arts, engineering began to resume that lofty position, and to again perform those wonderful works, which had marked the temporary but brilliant advance in civilisation during the times of the Alexandrian University. Leonardo led the van, and all men honoured him and his followers as such men had not

been honoured from the early days of history.

With the growth of agriculture and manufactures, necessarily sprang up commerce, and first the Saracens, and then the Europeans of the South, became rich. Leisure and scholarship and all culture followed, as always, in the track of the man of science and of the engineer. The steam-engine was born again, in the days of De Caus, of Da Porta, of Branca and of Papin, and the seventeenth and eighteenth centuries saw modern life fairly established.

The art of printing made this later, scientifically organised, civilisation impregnable against the assaults of either time or barbarism; its most impregnable bulwark remains to-day, and will probably always remain, the steam-power press, the material nucleus about which gravitates all that is best of the intellectual, moral, spiritual trinity constituting humanity. About this product of science, art, invention and genius gather and revolve the intellect, the heart, the soul of humanity. Through it, they promote, steadily and irresistibly, the sciences, the literatures and the arts, the morals, the manners and the culture of the race, and thus Archimedes's lever finds the fulcrum, resting on which it moves the world.

The current century has seen the most marvellous effects of the general adoption of scientific method in all departments of life. It has witnessed the complete organisation of all the physical sciences, the world-wide fruitfulness of applied sciences, the previously unimaginable productiveness of the mechanic arts, and the almost miraculous achievements of contemporary engineering. The steam engine, the factory system, the steamboat, the railroad, the telegraph, the telephone, the electric light and the electric railway, the mower and reaper, the harvester and binder, the threshing machine and the elevator, have made the whole world tributary to the agriculturist.

The spinning frame and the loom, the cotton-gin and the printing rolls, the woolen cards and comber, and the chemist's processes of bleaching and dyeing clothe the world. Man with his labour-assisting machine accomplishes more in a day than, during the Middle Ages, he could perform in a month. Wealth, comfort, luxury, and their inevitable accompaniments of higher culture and nobler life have come as the product of scientific method and of the introduction of applied sciences into the arts of the time.

Scientific method and the art of the engineer and the mechanic have made the glory of the nineteenth century possible. James Watt, man of science, mechanic, inventor and engineer of the highest rank, gained professional success and unending and world-wide fame by his constant employment of scientific methods. He adopted the scientific process at the start, and his inventions are the outcome, not of inspiration, as inventions are usually supposed to be, but of scientific researches, conducted by the most approved scientific processes of his time, and directed by deep thought and by the genius of the born investigator.

The scientific method, that of Aristotle, as distinguished from that of the non-scientific Greeks, consists in the observation and interrogation of nature, collecting facts and noting phenomena and all their visible and sensible relations, until, these facts and phenomena, having been collected in sufficient number and in sufficiently close relation, some evident sequence or formal connection can be discovered among them, and this, formulated, is enunciated as a law of nature, a foundation-stone of the science under investigation. Further research reveals other such aggregations of fact and relations of phenomena, and other laws are discovered. Presently, these laws are, by a similar comparative study, found to relate themselves to one another, through logical or material bonds, and a science is founded.

The science being thus erected into a definite and intelligible system, light is promptly thrown upon new aspects of nature, and facts and phenomena begin to come into the field of observation more and more rapidly as the investigation is thus more and more intelligently

directed. The new science quickly broadens, and, finally, takes into its widening area the whole world of related truths. Progress in practical life now follows the revelations of possible uses of the natural forces thus revealed, and the operations of nature are made tangible and utilisable. Applied science is the fundamental stratum in modern civilisation. It gave us the steam-engine, the steamboat, the railway, the telegraph and telephone, the most useful and striking of modern industrial processes. It has even given us new materials, metals like aluminium, alloys like those of steel with nickel, colouring matters like those of analine, and has even given us the synthesis of madder and thus displaced the product of the plant by that of the chemist's processes as conducted in great manufacturing laboratories. Thus Aristotle still lives and directs the progress of the modern world of engineering and industry.

Watt gave us his steam-engine, as has been remarked, as the outcome of the scientific investigation of an engineering problem. He observed that the existing machines of that class were using several times as much steam as their steam-cylinders would inclose uncondensed. He deduced the conclusion, instantly, that there must exist a defect in consequence of which, in the case of his own experiment, at least, three-quarters of all the steam entering the engine was wasted by condensation in the machine without performance of work.

He planned and completed a study of the nature, method, and extent of this waste, pursuing his research in the most scientific manner, and revealed clearly the facts that it was contact of the steam with cold metal at its entrance into the engine which produced this condensation; that steam, when condensing, surrenders to the cooling body several times as much heat as can be detected by the thermometer immersed in the vapour; that this "latent" heat disappears and reappears, with the vaporisation and the condensation of the fluid at a temperature determined solely by the pressure, and without the slightest alteration, during the process, of that fixed temperature. He thus deduced new and important scientific facts and this principle of application:—"It is necessary, in order to secure economical use of steam in any steam-engine, to keep the steam-cylinder as hot as the steam which enters it." This principle has given the world the Watt steam-engine, and the discovery of these facts has been the compass giving the course to all inventors from that day to this.

Watt and Sickels, and Corliss and Greene, and other inventors, have, during the current century, supplied the motive power of the world, and the Stephensons and Norris and Baldwin have made it possible to transport a ton a mile on railways at about one one-hundredth the cost of highway transportation in the days before the railroad. They and men like Fulton and Fitch and Stevens and Bell and Symington, have made it possible, to-day, to transport a ton one mile over the ocean for the quantity of fuel represented by a single one of the half-ounce letters in its mailbags. As some one has said, "James Watt, instrument-maker, conferred upon his country more real advantage than have all the treaties ever made, and all the battles ever fought."

It was the Aristotelian scientific method, in the hands of a genius, applied to a well-defined problem, that accomplished for the world, in a few short years, more than, in fact, had been materially gained by it in the whole two thousand years from Hero and Archimedes, Watt's earliest predecessors in that field.

This work permitted the extension of the cotton manufacture to its present enormous extent. Imported into the West by the Arabs, perfected as a hand-industry by the Saracens in Northern Africa and in Spain, it was by them given to Europeans about a thousand years after Archimedes, and with it came block-printing and dyeing and the manufacture of a crude paper. The Abderrahmans handed the arts over from the successors of the Alexandrian engineers and mechanicians to the pred-

ecessors of Da Vinci and Michael Angelo, and Arkwright, and Crompton, and Cartwright.

With Watt's steam-engine, this fundamental art found its opportunity, and the steam-engine soon drove the spinning frame and the loom. Twenty-five years after Watt's death, British cotton manufacture was spinning a length of thread, according to Baines, two hundred thousand times the circumference of the earth,—five thousand millions of miles. Aristotle had started a power of intellectual development of material things that, in 1833, produced a length of fabric that might girdle the earth eleven times or bind the earth to the moon. Aristotle and modern engineering may, to-day, be credited with many times these prodigious quantities. Each year we apply the steam-engine and the cotton-mill to the production of three or four thousand millions of pounds of fabric, and clothe the nations of the earth. A thousand steamships distribute it throughout the world.

Galvani, Volta, Gilbert, and the later electricians, adopting the methods of Aristotelian science, laid the foundation of electrical physics, and, in turn, the engineers, seizing upon this wonderful and still mysterious energy, compelled it to their own service in the distribution of "the desire of kings"—power. Morse built a telegraph line and electricity carries the messages of manufactures, trade, commerce, friendship, love, grief, and statescraft, and a nation's future hangs in the balance until the electric fluid passes across the wires and through the cables under the sea laden with the fateful message. Bell, man of science, philosopher, naturalist and engineer, all in one, applied this same singular power to the transmission of the human voice over intervening miles, and distant friends converse as if face to face.

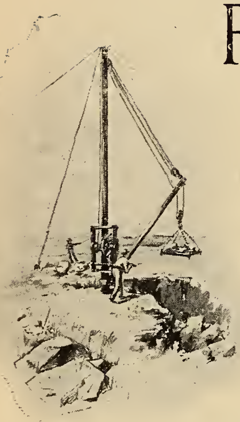
Those eminent engineers, Dudley, Cort, and their colleagues and successors, following the ways of the pupil of Plato, and the better ways of later disciples, learned how to smelt iron from the rock and to cast it into masses of tons weight, in perfect form and dimensions, to roll it into beams and rails and rods of all shapes and sizes, with the aid of Watt's steam-engine. The progress of civilisation has come to be measured by the weight of iron which a people consumes.

But the blessings are not of the past or of the present, alone. With the awakening of Science and the establishment, in all fields of research and of achievement, industrial as well as other, of the scientific method of Aristotle, we have seen, especially during the current century, a progress that has steadily become more and more rapid, productive and imposing. like the accelerated motion of a falling stone. Nature never brings a great social movement of this kind to sudden termination, and never turns a mighty mass about a sharp corner. This movement must go on for a long time, probably for many years, perhaps for many generations, and each new year shall see greater wonders than the last, each generation shall marvel at the progress made during the decades in which it lives.

Further advance depends upon the promotion of modern engineering through improvements in scientific method, discoveries in science, inventions, the arts, and industrial and professional training of engineer, mechanic, inventor. Germany, generations ago, discovered these facts and set about profiting by them, deliberately, systematically and doggedly. She is to-day reaping her reward. Great Britain has lost in that race, and America may well consider what impends if the education of a people for the life and work of a people be neglected.

SUBAQUEOUS ROCK EXCAVATION WITHOUT USING EXPLOSIVES

By Fred. Lobnitz



ROCK excavation is usually associated in popular fancy with the use of explosives. Under certain circumstances, however, a method is employed which entirely dispenses with dynamite and similar agencies. When rock is situated under water, breaking it up resembles working in total darkness, for the work cannot be seen; but the rock-cutting apparatus described in this article enables the rock to be treated with almost the same certainty as if it were visible.

Although almost exclusively used for subaqueous work, the apparatus has been worked on land; but on dry land explosives are easily applied, and can be used very much better than when the rock is under water. For subaqueous work, the rock-cutting machinery is, as a rule, mounted on a pair of barges, which are joined together by logs of wood, or steel girders bolted across their decks.

In principle, the apparatus provides for a heavy chisel of steel, weighing usually 10 tons or more, and falling repeatedly on the surface of the rock. This chisel is fitted with a hard cutting point, and is the tool by means of which the rock is broken, being raised by a hoisting rope, and then allowed to fall from a suitable height upon the cleaned surface of the rock. With a drop of from 6 to 10 feet the cutter breaks its way into the surface of the rocky bed, partly pulverising it and partly breaking it. When the rock is hard, it breaks like a piece of glass struck by a hammer.

The cutter, as it is called, is allowed to fall on the same spot until it has penetrated to the depth desired, after which the barge on which it is mounted is moved a short distance by means of manœuvring chains, which are worked by a special hauling winch, and then the operation is repeated. The distance apart between the points where the blows are struck is not always constant, but varies according to the experience gained concerning the nature of the rock. If the thickness of rock to be broken is greater than about one yard, it is usual to break it in layers, and dredge away about a one-yard thickness before breaking up the next layer.

The rock-cutters are graduated in feet and inches, painted on the surface. The length of the cutter is generally about 3 feet more than the greatest depth below the surface of the water which it is desired to reach. Accordingly, a part of the rock-cutter remains always above the water after a blow has been struck, and it can thus easily be seen, by reading off the scale on the cutter, to what depth the rock has been penetrated.

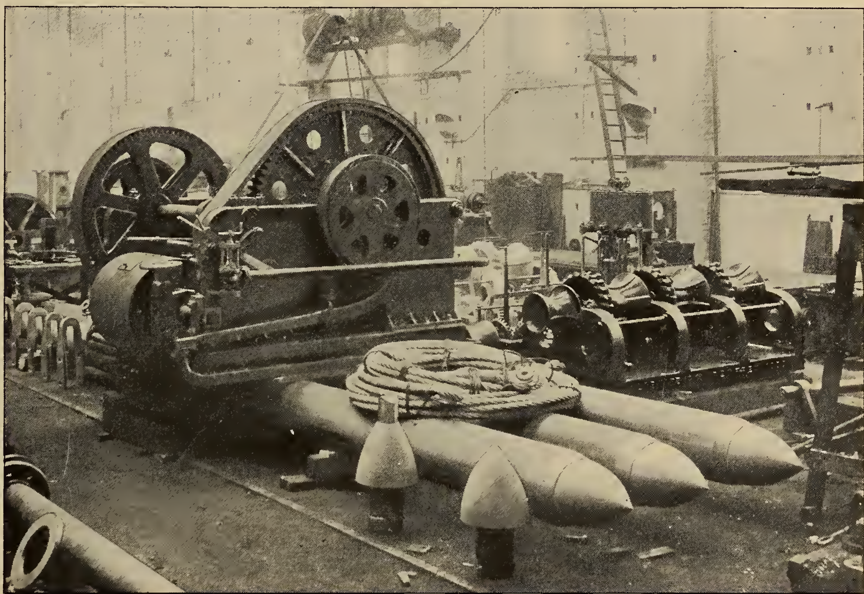
Before delivering a blow on an unknown spot, the cutter is lowered by means of the wire rope hoisting cable, and the point is allowed to touch the surface of the rock in order to determine the depth of water. After noting this on the scale which is painted on the cutter, a blow is struck with a fall of, say, 6 feet, and then one can see on the scale how much of the rock has been penetrated. The penetration is read off at each blow.

The form of cutter employed is usually

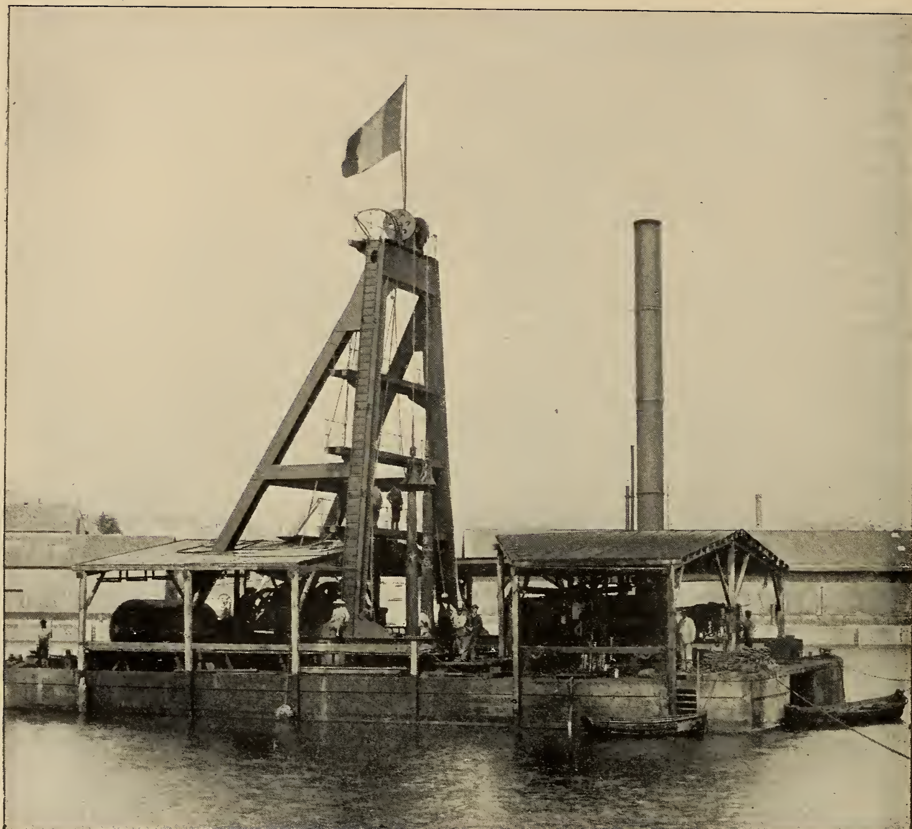
a round bar of special mild steel, turned smooth in a lathe throughout its whole length. The diameter varies, being greater at the centre than at the two extremities, and at the centre of the length of a 12-ton cutter it is upwards of 20 inches. The lower extremity is fitted with a cutting point similar in form to that of an armour-piercing shell. This point is fitted in a taper socket, so as to be easily and quickly replaced when worn. The top end of the cutter is fitted with a head, or bridle, constructed in such a manner that the hoisting rope automatically catches the cutter after each blow by means of a special device similar to that used in pile-driving.

The cutter is guided, but allowed to fall freely, through a hole formed between hardwood timbers. This guide is fixed between the upright timbers in such a manner that it can be raised or lowered by means of the hoisting rope, so as to vary the height according to the depth of water at which the cutter may happen to be working. When the depth of water is great, the guide is lowered clear down to the level of the water's surface. It has steel wearing plates, and between it and the upright timbers there are cushions, formed of india rubber or spiral springs, to deaden any shocks which may be caused by the point of the cutter striking an inclined surface of the rock.

There is an automatic device in the form of a bell, fitted to catch and release the cutter, similar to the arrangement used in driving piles. This bell-shaped covering is of steel, and allows the wire rope to catch the cutter even if its head has become inclined through striking an irregular peak of the rock. The bell has a lever, to the end of which a rope is attached, and the other end of this is fastened to the deck of the barge, so that, when the cutter is hoisted to a given height, the trigger rope becomes taut, inclining the lever and allowing the cutter to fall. The winch is so arranged that the moment the cutter is released the automatic catch rapidly descends, following the cutter speedily, and without loss of time the head of the cutter is again caught and the cutter raised, ready to deliver another blow. This catch is of such a



CUTTER BARS AND POINTS



A DOUBLE-CUTTER OUTFIT

weight as to counterbalance and run out the wire rope rapidly, and the operation of catching the head is automatic, as the lever is worked by a strong spiral spring.

The hoisting winch is a powerful steam-engine with suitable gearing and special fittings to allow of continuous work. About 1000 blows per day of 10 hours can be given regularly.

The manœuvring winch is a most important part of the machinery, as it is obviously essential to be able to deliver repeated blows on the exact spot desired. For this reason six manœuvring chains are used. Four side chains are used to traverse the work, permiting blows to be delivered in a straight line the whole width of the channel, spaced about 2 feet or more apart, according to the nature of the rock. After completing the width of the channel, the barge is advanced by means of the head and stern chains 2 feet or more. The apparatus is then manœuvred in the opposite direction, across the width of the channel. The manœuvring winch is so arranged that the amount of chain taken in on the one side is exactly equal to the amount of chain given out on the other side. The six barrels on the manœuvring winch are each independent, Smaller barrels are also provided with a quicker speed, for rapid warping, when desired.

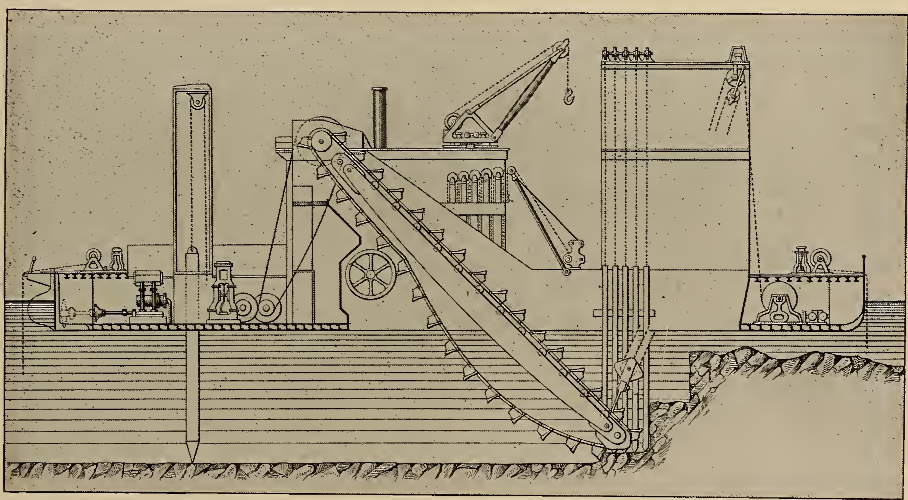
As accurate manuœvring is important, exact base lines should be established on shore. On the barges which carry the rock-cutter two vertical rods are fitted in a frame. These rods can be placed in different holes two feet apart, or whatever distance may be desired

between the points. These two rods then form two sighting points, which should be sighted in line with two other rods ashore. The rods ashore are set up square to the base line, and the rods on board the rock-cutter barge are shifted two feet every time the barge is advanced, so that the rods on shore do not often require adjustment. The distance from the base line is generally measured by means of a graduated wire. In cases where the base lines are too far away for this method, a telescope with a base graduated in degrees is mounted on the barge, and by this means very accurate results can be obtained. At night the sighting points are distinguished by lamps.

According to the nature of the rock, the wear of the points of the cutters varies greatly. In some works of large extent the whole of the rock has been broken without completely wearing out a single cutter.

A much larger cube of broken rock can be done when the blows are spaced more than two feet apart; but this advantage is entirely lost when, later, the rock is to be dredged, because, when the rock is broken small,—say to ballast size,—it is dredged very easily and quickly, whereas breaking the rock into larger pieces makes the dredging much more costly. With a very little practice the man in charge can regulate the dimensions of the broken rock exactly, as may be desired.

With a strong dredger, rock broken by cutters is very easily dredged. With a feeble dredger the cost per cubic yard dredged is much greater than with a powerful machine. The reason of this is that the part of the rock which is broken up by the rock-cutter is generally left for a month or more after being broken. The action of the water brings sand and other *débris*, which fill up the spaces between the pieces of rock, so that a weak dredger could not lift it. Again, unless the dredger is powerful, it is difficult to scrape the surface of the rock entirely clean, as, when the buckets scrape on the solid rock, breakages are caused.



LONGITUDINAL SECTION OF A ROCK-CUTTING AND DREDGING BARGE

For each quality of rock there is a certain hardness and style of cutter point which is the most suitable. It is difficult beforehand to know which temper of point would be best. All the points are made harder in the centre than on the outside, so that they remain automatically sharp, on the same principle as a rat's tooth. Therefore, generally two or three different kinds of points are tried, and the most suitable shape and hardness of point show

themselves after a few months' work. The average results from much work in hard rock have given two cubic feet of rock broken for every blow struck, and broken to the most suitable size for dredging. In most of the work one hundred blows per hour are delivered, which is equal to, say, 7 cubic yards per hour for a single-cutter machine.

On a rock-cutting barge there is generally a surveyor, who takes note in a book of the number of blows and the depth to which the cutter has penetrated at each point of the surface. It is, therefore, always possible to be thoroughly certain that the rock is really broken to the desired depth at any given point by jotting the notes in this book on to the plan. It is necessary that the point of the rock-cutter should penetrate about 9 inches below the section on the drawing, so as to be quite sure that the buckets of the dredger will not catch on the solid rock. The book in which the blows and other data are recorded is generally divided into numbered columns, so that there is only the depth to be written in at each blow in the space provided, corresponding to the section on the drawing.

The points are fitted into the cutter by means of a slightly conical end, and can, therefore, be easily replaced. To prevent the point, which weighs about 500 pounds, falling out of its place, a screw is inserted flush with the surface of the cutter. When a point has to be changed, the cutter is hoisted so that the point comes above the deck of the barge. Then, by unscrewing the screw at the side, the point falls out, after, if necessary, a blow from a hammer. A plank is placed to receive the point when it falls. The new point is placed on the plank, and the cutter is lowered on to the top of it, and the screw replaced to hold it in position. This whole operation has been done in a few minutes.

To change a whole cutter when required, there are chains with hooks attached to the automatic catch. With these chains the cutter is lifted so that its point comes above the deck level. Then it is gradually lowered and pulled to one side by means of the warping ends of the manœuvring winch, so as to lower the cutter sideways on to the deck. It is then slipped on to a barge, or on to the quay wall, if there be one. The new cutter, being brought alongside by a barge, is lifted direct into its place by the hoisting winch. In certain cases spare cutters remain always suspended on the framing alongside the working cutter. By this means, in case of accident, say, when the cutter is dropped into the water, or is broken, the spare cutter can be working in about a quarter of an hour after the accident. Except in very hard rock, it is quite unnecessary to have spare cutters on board the barge.

If, by allowing the cutter to penetrate too far, or, by dropping it into a fissure of the rock, it should stick fast, it can be withdrawn by manœuvring the barge gently from side to side; this loosens the cutter, so that the hoisting winch can readily draw it out. If the rock-cutting barge has two or three winches and cutters, the usual way is to attach two hoisting winches to the one cutter to withdraw it. But the cutter very rarely sticks fast.

Six men are required on a rock-cutter barge with one cutter, and eight to ten men on a rock-cutter barge with two cutters. Skilled labour is not required, as the apparatus can be worked with the greatest of ease without any special skill. The experience necessary is rapidly acquired.

The coal consumption is about one ton per day of ten hours for an apparatus with one cutter, one and one-half tons per day of ten hours for an apparatus with two cutters, and about double this quantity for night and day work.

In most of the recent large rock-excavating works the rock-cutter system here described has been adopted, as the results obtained are very much more regular and rapid, and far less costly than with any other method. A rock-cutter of this kind was first used to remove a large quantity of rock in widening the Suez Canal. These first cutters were of only 4 tons weight, and the results obtained now, with heavier ones,

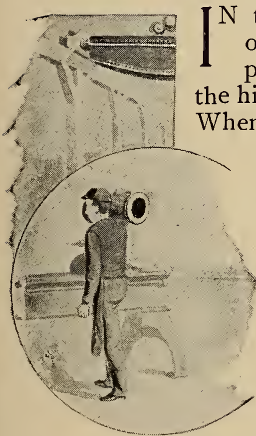
with perfected points, are greatly superior to those first reached. Large machines, with from one to three cutters each, have been used in a number of important enterprises in different parts of the world, and with uniformly pleasing results. All these machines were built at the works of Messrs. Lobnitz & Co., Ltd., Renfrew, N. B., Scotland.

Rock excavation with such cutters is always much more certain, less costly per cubic yard excavated, and also much more rapid, than with any other system known until now, for subaqueous rock-excavation.

THE VALVE GEAR OF THE WILLANS ENGINE

By John Svenson

From a Paper Read before the American Society of Mechanical Engineers



IN the critical examination of any mechanism, simplicity is, without doubt, the highest test of excellence. When, therefore, in the gradual evolution of a certain piece of machinery great simplicity has been approached without loss to the result required, that particular combination of mechanical elements becomes an object of general interest. It is this thought which furnishes me with an apparently valid motive for leading you to a moment's notice of a steam-engine valve gear which has in its make-up so few moving parts, and which effects a steam distribution so admirable, that it may well be reckoned among the mechanisms above categorised.

The valve gear of which I am about to speak is not new. It is probably known to many as the most interesting feature of that engine which, of all strictly high-speed prime movers, has attracted the greatest attention in Europe, and which was the cause of bringing the late P. W. Willans before the world as one of the foremost steam-engine experts of our day.

While thus lacking in absolute novelty, my subject—may nevertheless interest those who have not as yet become entirely familiar with this admirable gear.

The valve mechanism of the Willans engine is so closely interwoven with the other reciprocating parts that, in order to render a description of it at all comprehensible, it will be necessary to include here a few brief references to the engine as a whole.

From a study of Fig. 1 we see an engine of the vertical type with single-acting cylinders—in this instance two in number—arranged tandem fashion over a common crank shaft. A peculiarity of design will strike you at once in examining the piston rod. Contrary to usage, this element is here a tube, open at both ends and finished accurately inside and out. It runs steam tight through glands provided with elastic packing rings. At proper intervals it is pierced with openings, arranged in transverse rows, through which the steam is made to enter and leave the cylinders, the admission and exhaust periods being regulated by the valve and by the movement of the rod itself. The valve is a series of connected pistons working inside the hollow piston rod. It is made to run steam tight by means of spring rings.

For the other portions of the valve gear proper, the briefest kind of reference will suffice. They are an ordinary eccentric with its strap; a rod secured

to the strap in the usual way, and to the valve by means of the only pin about the whole gear; and, finally, a small cross head with guides. As the piston rod is also the valve seat, the rod and the valve must move in relation to each other. This relative motion is obtained by mounting the eccentric upon the crank pin.

The valve opens the inlet ports; it also alone controls the exhaust, but it

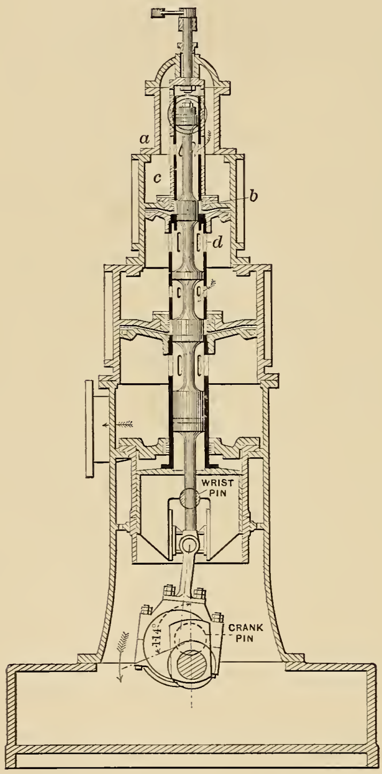


FIG. 1—VERTICAL SECTION OF A WILLANS ENGINE

does not cut off the steam supply at the end of the admission period. That office is delegated to the care of the hollow piston rod, which then, to that extent, becomes a member of the valve gear. The manner in which the rod performs this part of its work will be best described in connection with the steam distribution. I will merely mention here that the arrangement not only permits a variable automatic cut-off, but it also gives rise to a rapidity of cut-off not heretofore attained with so few moving parts.

The eccentric has no part in varying the cut-off. This member is unalterably secured to the crank pin, and it has been found that an angular position of 114 degrees ahead of the crank is the most advantageous.

The steam distribution is, briefly, as follows:—When the parts are in the position shown by Fig. 1, the crank being at the upper centre, steam from the chest has free access into the hollow piston rod between the two highest valve spools. Ports *b* are also opened to the extent of a slight lead. As motion commences, these ports *b* are very rapidly opened. That such is the case is plain from the fact that the eccentric at the beginning of admissions moves very near the position of maximum speed of valve travel. On the downward stroke, while steam rushes in through the ports *a* and *b*, on top of the piston, a point will be reached when the ports *a* will be covered by the solid portion of the sleeve *c*. Then the inflow of steam will cease and expansion begin.

Just before the crank pin has reached the lower centre, the valve, which is now on its upward path, has arrived at a point where the lower edge of the second valve spool coincides with the lower edges of the ports *b*. This marks the beginning of the exhaust period. The same rapidity of opening that characterised steam admission is again repeated in the release, as the valve now also moves in close proximity to the locality of greatest speed. The exit of steam is through the ports *b* and *d*, into the space beneath the piston, which space is either a receiver, or an exhaust chamber connected with the exhaust pipe, as the case may be.

I need hardly say that the cycle described above for one cylinder is repeated in every other cylinder located beneath. If the gear is used on a simple engine, the valve has three spools or pistons, and the operations noted end the matter. In a compound or triple-expansion engine two more spools must be added to the valve for every cylinder

below the first. No matter how many cylinders may be used in one line, the same events of admission and release occur in them all simultaneously. The points of cut-off may, however, be varied to suit conditions.

I will return to the first portions of the cycle to consider for a moment the cut-off arrangement. It should be first noted, then, that when no variable cut-off is desired the sleeve *c* is removed, the upper portion of the hollow piston rod somewhat shortened, and the packing gland adjusted to the proper height, so as to serve the purpose of arresting the steam supply through the ports *a*, at the proper point.

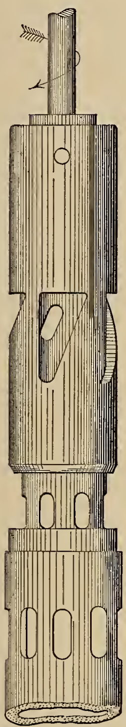


FIG. 2—THE CUT-OFF DEVICE

The automatic cut-off device is the sleeve *c*, fitting nicely on the outside of the piston rod, and arranged to rotate when acted upon from the outside by a centrifugal governor. Reference to Fig. 2 will indicate the purpose and effect of such rotation. The inlet ports *a*, of the down-moving piston rod, being in communication with the steam chest only through the triangular apertures cut into the sleeve, will become closed earlier or later, dependent on the angular position of said sleeve. By this means the period of expansion is varied to correspond with momentary changes of load.

Where the demand for accuracy of regulation warrants the expense, a similar cut-off sleeve may be fitted on the piston rod above the low-pressure cylinder also.

It is interesting to note that no matter how many cylinders may be in use, so long as they are placed in one line, the valve gear still retains but one pin connection and one eccentric. The gear is, therefore, in the principal sense, no more complicated in a triple-expansion engine than it is in a simple engine. The valve, to be sure must be longer, but an addition of valve spools is the least objectionable, as furnishing but increased weight. This feature of simplicity in a multiple-cylinder engine becomes of the utmost importance when an engine of high rotative speed is considered. The fewest number of jointed parts is here absolutely essential to maintenance, long life, and safety. A gear, then, which provides the wanted simplicity, enables the high-speed engine to multiply its cylinders, and will for that reason permit it to take its place among the economical engines of our time.

The locality of the valve and its operating mechanism in the very centre of the engine develop several very interesting advantages. The steam passages become singularly direct, clearance spaces small, and the general compactness is rather conducive than otherwise to the lessening of heat wastes. All strains, barring those due from the angularity of the connecting rods, are transmitted along the centre line of the engine, and the greater number of the construction details take naturally that form,—the round,—which is, without question, the most favourable for shop manipulation.

I need not enlarge on the evident fact that the valve friction is no greater than the amount due to the tension of packing rings. In this sense, then, the valve is unquestionably balanced. From another point of view it may, at first sight, appear that the valve suffers resistance to motion in overcoming the unbalanced steam pressure which is allowed to act with full force on the top spool. But while this pressure, of course, is a load on the up-stroke, it tends, on the down-stroke, to assist the crank, so that the total effect should be *nil*.

It would not be necessary to allow any top pressure at all when the gear is used in a slow-running engine. But in connection with the higher rotative speeds, the frequency of stress due to

oft arrested momentum of the valve mass would seriously tend to rupture, if not neutralised. The same force will also, in a high-speed engine, cause destructive hammering in the eccentric strap, so soon as wear has developed lost motion. A constant pressure on top, however, will absorb the momentum, and keep the wearing parts in unchanging contact. All stress in the moving parts of the gear is by this means converted into compression, which state of things has the incidental advantage of lessening the "fatigue" in the materials used, for the reason that no stress is reversed in direction.

A summary of the various characteristics possessed by this valve gear brings out a very flattering result:—Minimum number of parts, and simplicity of form and construction; a free inlet and release, and a cut-off so sharp as to rival even a Corliss; a balanced valve of the piston type, with very small clearance spaces, and which, by virtue of its position, is easily kept steam tight; great facility for varying the cut-off; perfect adaptability to the difficulties of high rotative speed.

Such are, in brief, its leading advantages. I can think of but two shortcomings. One is that the limit of its general adoption in the form here represented is reached in an engine having single-acting cylinders only. The other is the difficulty of arranging it to run reversing. The first objection, and perhaps the second as well, will have but slight effect on its destiny, insomuch as its proper field of action will be confined to the high-speed engine, where single-acting cylinders will, in all probability, prevail.

HOW THE PYRAMIDS WERE ERECTED

By W. F. Durfee, C. E.

WHILE there is no reason to dispute the possibility of the ancients having used, at times, inclined planes, or "ramps," of earth to facilitate the construction of large edifices, in a way like, or similar to, that suggested by Dr. J. Elfreth Watkins in his article on "The Transportation and Lifting of Heavy Bodies by the Ancients" in CASSIER'S MAGAZINE for ~~November,~~ December 1898, it does not seem probable, in view of the evidence available, that such "ramps" were used in the erection of the pyramids; for we have the positive statement of Herodotus that the huge masses of stone of which they were built were put in place by quite a different method.

In an old French work, entitled "The Origin of Laws, Arts, and Sciences, and Their Progress Among the Most Ancient Nations," of which an English translation was printed at Edinburgh in 1761, President de Goguet remarks:—

"I have said that the great pyramid was built almost throughout of stones of enormous size. Our modern authors have reasoned much and formed many conjectures to explain by what means the Egyptians could raise such enormous masses to the height at which we see them. These doubts have probably been occasioned by some writers of antiquity, who speak of that operation, but in a very vague and uncertain manner. Diodorus says that they accomplished the building of the pyramids by means of terraces disposed in an inclined plane. He adds to this account such circumstances as cannot fail to render it very suspicious to any one who will reflect upon it. What we read in Pliny is subject to the same censure. This author seems to have copied Diodorus, not omitting, however, to diffuse his usual obscurity on what he borrows from the Greek historian. Nevertheless, it was very easy, by consulting Herodotus, to form a very simple and a very just idea of the manner in which the pyramids were constructed.

"According to this great historian, the pyramids were formed by distinct courses of stones, which courses successively diminished in size as the proportions of the edifices required it. Every course was so much within that immediately below it as to make each front of the pyramid form a sort of stair. The accounts of modern travelers agree perfectly with this. It is even now easy to count the number of courses which formed the great pyramid. This fact being admitted, we see that only time and patience were necessary to raise the heaviest stones to any height whatever.

"A very simple machine, and, according to Herodotus, very easy to manage, placed upon the first course, served to raise the stones destined for the construction of the second. The second being finished, another machine, of the same kind that I have been speaking of, was fixed upon it, and so on for the rest, one or more of the machines being always left upon each of the courses already laid, to serve successively for raising the stones from step to step. By repeating this operation as often as was necessary to form the

FROM AN OLD PRINT

CONSTRUCTION OF THE PYRAMIDS ACCORDING TO HERODOTUS

height of the pyramid, they accomplished the raising of the stones with ease to its utmost summit. Such, by the report of Herodotus, was the manner in which the body of this monstrous edifice was constructed.

"The same author teaches us also the method which they followed for the exterior covering of the pyramid, for it is certain that the pyramids had all, originally, an outward coat, whether of square flags, or marble, or of bricks, or of small stones, in such a manner that they presented to the eye only a perfectly even slope, such as we see at present in most of these buildings. It is true that at this time the great pyramid presents to us on each of its sides only a kind of stair; but it is easy to convince ourselves that this enormous mass was originally overcast with marble, which has disappeared through the injuries of time, or rather, by the avidity of the Arabs. Herodotus tell us, then, what good sense alone would have dictated,—that is to say, that they began the coating of the pyramid from the summit."

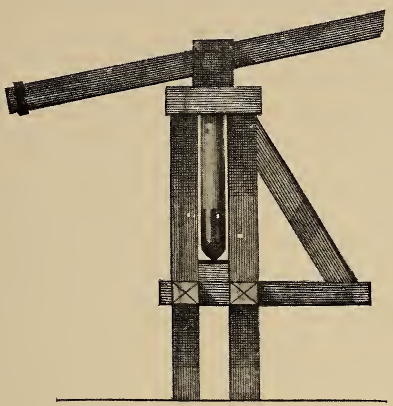
Rawlinson, translating Herodotus, tells us that "after laying the stones for the base, they raised the remaining stones to their places by means of machines formed of short wooden planks."

The accompanying engravings illustrate Goguet's conception of the kind of mechanism employed by the pyramid builders. It is substantially a lever crane. Cranes on this principle were well known at a very early date. The lever was in common use in ancient Egypt, and the pulley was also known and used prior to the destruction of Nineveh (B. C. 625), and is found figured among the sculptures discovered in the ruins of that great city by Ledyard.

That some species of hoisting mechanism was used by the old Egyptians for placing obelisks in position is known from the statement of Pliny, that Rameses (1250 B. C.), fearing that his engineer would not take sufficient care to proportion the power and strength of the machinery employed to raise an obelisk ninety-nine feet in height, to the

great weight to be elevated, ordered his own son to be bound to its apex, to more effectually insure the safety of the monument.

The inclined plane,—the simplest of the elements of mechanism,—was, with-

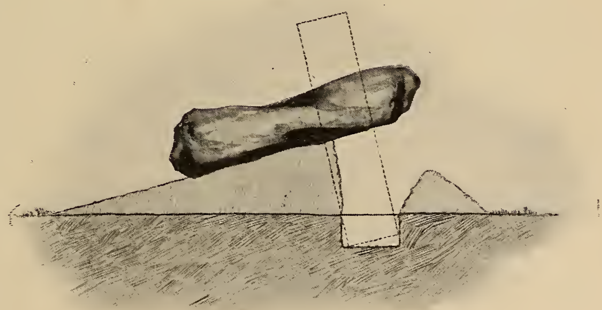


ELEVATION OF THE HOISTING MECHANISM SHOWN ON THE OPPOSITE PAGE

out doubt, the earliest mechanical expedient used by man for raising large masses. As a preliminary to the building of the great pyramid, the engineers of Kufu (Cheops, 3050 B. C.) constructed an inclined plane of masonry for raising the stones from the level of the river to that of the rock platform on which the pyramid was erected,—a height, according to the French survey, of 144 feet above the mean level of low water in the Nile. This inclined plane, or causeway, was over 3000 feet in length, and had a width of 60 feet. Its eastern end was contiguous to a canal communicating with the Nile, by which the boats carrying the stones from the quarries could deliver them in readiness to be dragged up this vast "ramp,"—doubtless the first artificial construction of the kind,—on sleds, by men or animals, to their destination.

Although it is very evident that earthen "ramps" were not employed in the building of the pyramids, it is certain that at a much later date they were largely used in the erection of temples in India. Col. Wilkes states that "the immense stones were moved end foremost, up an inclined plane of solid earth, of as small an angle with the horizon as circumstances would admit, to the spot which they were to occupy in the wall. Long bamboo poles, lashed to the stone at right angles to its length, at such distances as merely to admit the efforts of rows of labourers between, constitute the chief means of propelling it by main force up the inclined plane, and its ascent is facilitated by means of rollers of small diameter, successively introduced under the stone, and prevented from sinking into the earth by rows of planks placed on each side of the stone, parallel with the line of ascent."

It is not many years since the inclined plane was common in all our shipyards (there called "the brow"), and in our early history it was used in the construction of large buildings. The writer's grandfather once told him that "all the stone and mortar used in the walls" of a certain cotton factory "were dragged up inclined planes on 'stone-boats' by oxen, even to the top of the building." These inclined planes were made of timber and plank.



DOUBTFUL METHOD OF USING EARTH EMBANKMENTS FOR RAISING MONOLITHS

With regard to the transportation of such large stones as those at Baalbec, it is not at all necessary to suppose that

there was any great difficulty in so doing at the comparatively recent date of their employment, for it is well known that about 500 years before, Chersiphon, the architect of the great temple of Diana at Ephesus (600 to 560 B. C.), —which was accounted among the seven wonders of the world,—included in its design one hundred and twenty-seven columns of marble, 60 feet high and about 7 feet in diameter.

Vitruvius states that Chersiphon, observing that the roads were not firm enough to bear the weight of such vast columns upon carriages, whose wheels would sink into the ground, contrived a frame, consisting of four timbers inclosing the rough hewn column. At the centre of each end of the column he fixed a large iron pin, secured with lead. The projecting ends of these pins passed through iron bearings in the end cross-pieces of the frame. Poles of oak were secured to two of the corners of the frame by iron hooks and strong iron rings. Oxen were attached to these poles, and as they moved forward the column turned and was drawn with no great difficulty to Ephesus,—a distance of eight miles.

Following out the idea of Chersiphon, his son, Metagenes, who succeeded him as architect of the temple, contrived a method for conveying architraves, some of which were 30 feet in length. He made strong, broad wheels, about 12 feet in diameter, in the centre of which he fixed the architrave, having large iron pins in the middle of each end. These pins turned in bearings in the end cross-pieces of the inclosing frame, the same as in the case of the column, and oxen were attached, as before described.

Earthen embankments have been used in India from a remote antiquity as a means of placing in an erect position obelisks and similar monoliths; but the method used was quite the opposite of that suggested by one of Dr. Watkins's illustrations in this previously mentioned article. [The illustration in question is reprinted on the preceding page.—THE EDITOR.] Judging from that figure, one would suppose that the monolith was about to "take a header" into the pit between the two mounds. It is easy to see that something would be very likely to happen to the crest of the left-hand mound when the stone was balanced like a scale beam upon it, and, even if it succeeded in making the dive contemplated in the figure, there would be grave liability of lateral inclination and prostration, to say nothing of the chance of its momentum carrying it beyond the perpendicular to the right. The ancients did not work in violent and spasmodic ways.

As illustrative of the method of erecting obelisks by the use of earthen embankments, the writer cannot do better than briefly quote from the description of the placing of an obelisk, 80 feet in height and 6 feet square at its base, by native workmen at Seringapitam in 1815, as given by Dr. Kennedy. He says:—

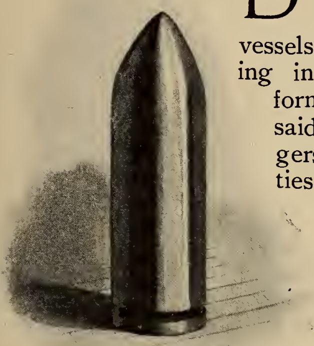
"The elevation was, at first, accomplished by men prying with handspikes over timbers arranged parallel with the obelisk, and, as it rose, earth was solidly rammed beneath it."

This method certainly had the advantage of a maximum degree of safety; and, as the operation was conducted exclusively by native workmen, by their inherited ways, it is pretty safe to assume that by similar methods all such masses had been raised in India from the earliest times.

ENGINE ROOM EXPERIENCE IN WAR TIME

On Board the United States Cruiser "New York"

By F. M. Bennett, Passed Assistant Engineer, U. S. Navy. Late of the U. S. Armoured Cruiser "New York"



DURING the dozen or more years in which fighting vessels have been changing into their present forms much has been said about the dangers and responsibilities that the development has brought to the engineering staff. In even the largest of the older types of warships,—the famous *Hartford*, the *Trenton*, or the *Franklin*, for examples, of the United States Navy,—the post of the engineer was on a working platform over the horizontal cylinders, and nearly, if not quite, as high as the level of the berth deck. Above him was a large hatch or trunk, wide open to the spar deck, through which he could see the sky and hear all that was doing in the management of the ship. It also supplied him with fresh air, sometimes too liberally when sails overhead were set, as the writer recalls many instances of wearing an overcoat on an engine-room watch. No watertight bulkheads or air locks interrupted the unity of the power plant; the engineer from his station commanded an unobstructed view of the fire-room as well as of the engines, and he could reach any part of his domain with his voice. In the final emergency, escape from engine and fire rooms was quickly and easily made by ladders, extending to the upper decks.

All that has been changed. Watertight bulkheads, air-tight fire-rooms, and battle hatches have transformed the engineer's place of duty into a number of steel cells, almost as inaccessible, one from another, as though they were in different townships. Instead of one big engine-room there are now two, three, and even four, each in its own watertight compartment, and the big street-like fire-room, into which the sunlight used to shine, has given place to as many as eight narrow black holes, cased in from all the world.

Even the long shaft alley that was the comfortable home of the grizzled old-fashioned fireman, whose passing we regret, has become two or three steel-locked dungeons into which one cannot enter without instinctively making sure that rapid escape is possible. The engineer no longer has his duties under control of his own eye and voice, but must fret his nervous system by depending upon the action of subordinates, whom he can direct in an imperfect manner only through a system of communication as complicated as a city telephone exchange, and much more liable to derangement.

That these new conditions have put greater responsibilities upon the engineer and his men is as obvious as the fact that the same conditions have greatly increased their dangers and discomforts. Many word pictures have been drawn showing the engineer at his post in the bottom of the ship, remote from succour in disaster, in an atmosphere like that imagined of hades, calmly directing a great development

of power, and bravely awaiting the arrival of a dire calamity, always pictured as impending. So general has become this impression of the mechanic's life afloat that even the makers of rhyme have found in the engine-room a new hero, and many verses have sung the praises of the "Jackie vot's a-stokin' down below," ranging in merit all the way from the stately march of McAndrews' Hymn to the doggerel of the daily press.

No one can grudge this poetic praise to the man at the stop-valve and the furnace door. In the conversion of ship locomotion he is the natural successor afloat of the old-time sailor, and is rightfully entitled to the place of the latter in panegyric and public admiration. Romance wove a multitude of dangers about the sailor, but in real life he usually escaped them and died in peace on a farm in the fulness of time. In like manner the new naval hero below decks has escaped the whole train of evils predicted for him, though he has passed through a war that was supposed to bring these dangers to the front. Had the Spaniard in his recent unpleasantness with the United States been resolute and enterprising, this might have been different. As it was, no use was made of the weapons supposed to be most destructive to the engineer,—the ram and the torpedo.

The only attempt to use either that the official accounts have brought to light was the firing of two torpedoes at the *Merrimac* when she was seeking to sink herself; they both missed, and were, later, found floating at sea, one perfectly harmless, as it had been fired with the exercise head attached instead of a war-head! Freedom from disaster from these sources did not, of course, remove the always present feeling that destruction might come quickly at any time.

But for the smaller complement of men allowed in time of peace the navy may be said to be always on a war footing,—that is, the guns are mounted in place, with ammunition, coal, provisions and medical stores always on board, and the personnel is kept always trained in its various duties. Therefore, when the Spanish war came upon us, it brought no violent change of daily custom,—simply a keying up of the whole naval fabric and an added alertness in the performance of duty on the part of officers and men. The conditions for which we had been training for years had at last arrived, and we did not find them novel.

With us the war dated from the destruction of the *Maine*. The *New York* was then at Dry Tortugas, coaling from a schooner alongside, and got the news of the tragedy about five o'clock in the morning after it occurred. At ten o'clock we shoved off the schooner, before the coaling was finished, and went to sea, steaming rapidly over to Key West, where we anchored, about seven miles off shore, and took up a war routine. Steam was kept ready for instant use, the first order being to turn the main engines every hour; this was afterwards modified to once a watch, or every four hours, and, after a few weeks, when the possibility of an attack had become remote, the engines were turned only once a day.

From the date of our arrival at Key West until after the destruction of Admiral Cervera's fleet, a period of about five months, the *New York* was always under steam and a sea watch maintained. The men had no shore leave during that time; indeed, there had been no general liberty since the ship left New York in December before, and very few of our men set foot on shore until after the return home of the ship in August. Notwithstanding this, they were cheerful and contented, working hard on watch at sea and much harder coaling ship night and day on the rare occasions when at anchor.

We were nine weeks off Key West before actually going to war, advantage being taken of the time to clean and repair wherever needed and put everything as ready as could be. The *New York* has two small auxiliary boilers above the protective deck that are seldom used. From one of these we led a 2½-inch pipe down to one of the forward engine-rooms, where it was con-

nected into the main condenser, and a fresh water distiller was thus improvised.

For the information of readers not familiar with the machinery arrangement of the *New York* it must be explained that she has four separate triple-expansion propelling engines, arranged in pairs fore-and-aft, each pair driving one of the twin screws. The forward engine of each pair is seldom used, being uncoupled from the crank shaft of its running mate, which made it possible to use the condenser and circulating pump of one of these engines for the extemporised distiller mentioned.

Besides saving our own boilers, the fresh water thus obtained was of infinite value to torpedo-boats and other small craft that otherwise might have ruined their boilers by using salt water. We stored the surplus water in the double bottoms and supplied our satellites, even in rough weather, by means of long hose led to them as they rode astern. Our ship had an evaporating plant sufficient for ordinary needs, but not for supplying fresh water for all the main boilers when in use at the same time.

Besides giving fresh water, the *New York* was good to her nurslings in other ways, particularly in attending to their many little ills and injuries. Because of our poverty in vessels of suitable types for carrying on war, all sorts of duties had to be demanded of those we had. Monitors had to act as cruisers, and were expected even to chase blockade runners, while harbour tugs, roughly converted into gunboats, took turns with battle-ships on blockading stations. The little ones,—torpedo and tug-gunboats especially,—had no facilities for making their own repairs, and, because of their size, suffered most from constant steaming in rough water. Consequently, it was seldom that one came within hail without offering bent and broken pieces of machinery for repair, and our machine shop usually had enough work on hand to have delighted the heart of the owner of a jobbing shop of like capacity.

That we were able to keep up this extensive repair work without weakening our watch force of mechanics was due to the introduction of a number of extra men enlisted for the war. The *New York* received sixty men of this description, which increased her engineering force to something over two hundred. Eighteen of the extra men came to us with the rating of Machinist, 2d Class, and were mostly machine-shop hands from small towns. A few had some experience with machinery afloat, and these we sent, whenever asked for, to the small craft, to stand watch in the engine-rooms, for we gave away men, as well as other necessary things, to keep the smaller vessels in fighting trim.

The country machinists, without knowledge of marine engines, and in some cases without experience with any form of steam engine, were not very useful in our big engine-rooms, where the multiplicity of machinery, big and little, bewildered them. But their experience in small shops, where makeshifts and improvised methods with inadequate tools are necessary, made them really more serviceable to us than men from highly equipped city shops would have been.

The machine shop on the *New York* was run twenty-four hours a day whenever there was work on hand, the machinists standing watch in three watches, the same as the running force in the engine and fire rooms, and turned out many pieces of work that, in quality and speed, would have been creditable to any shop on shore. Without these countrymen I hardly know how some of the small vessels could have been kept going, and I am glad of the opportunity to mention the really important service that they rendered their country. They contributed quite as much to the success of the navy as did the famed "man behind the gun," and, indeed, on more than one occasion they made the latter's performance possible by repairing ordnance material that had been damaged beyond the ken of the men who handled it.

The horrors of the engine department in battle, so liberally predicted, were not realised on board the *New York*, whatever discomfort or actual suffering may have been experienced in other

vessels. This freedom from torture was chiefly due to the very large ventilators with which that ship is fitted, these being sufficient to keep the engine and fire rooms at a living temperature. When steaming rapidly ahead, as in chase, the forward fire-room especially was not noticeably warmer than the outside temperature, while the volumes of air that came down the ventilators had a marked influence for good on the draught of the furnaces.

Though our operations were within the tropics, and in mid-summer, I find that the highest engine-room temperature during the war recorded in the *New York's* steam log is 103 degrees, the usual record being from 90 to 96; the usual fire-room temperature was about 110 degrees, the maximum, 125. Other ships, the monitors particularly, were hotter, and I remember one instance, on the expedition to Puerto Rico, when the *Amphitrite* had to be towed because she signalled that her engineers' force was exhausted.

Ventilators, in themselves, are of no benefit to fires or firemen unless they are used for the purpose for which they are made. They are sometimes used as ornaments, the hoods being uniformly trimmed either forward or aft, as may be thought best to add to the external appearance of the ship. Commanding officers, by virtue of position, have the right, unique on board a war vessel, of entertaining opinions. One, held by the captain of the *New York*, and enforced by him on every occasion, to the great satisfaction of the engineers, was that the ventilators should be kept trimmed to the wind to catch any air that might be moving. This was seen to, even in battle, with the results that suffering from heat was prevented below, the fires were not smothered for lack of oxygen, and the men were not obliged to live on what has aptly been termed "canned air."

Another reason for convenience, and real efficiency, in fact, was that, after the first one or two experiences, we did not observe all the prescribed preparations for battle. In practice, it was found unnecessary, and in some cases impracticable, to shut all the battle hatches, air locks and watertight doors when preparing to go into action. The use of forced draught with the closed fire-room system would, of course, require all openings to the fire-rooms to be tightly sealed, but the *New York* did not have to resort to forced draught on any occasion during the war, though she probably did more chasing than any three ships on the Cuban coast, and caught every vessel she chased.

Sufficient air reached the furnaces to make all the steam required, except on the rare occasions when a breeze from astern, about equal to the speed of the ship, would neutralise the action of the ventilators. "Assisted draught" was then resorted to,—that is, the fire-room blowers were run at moderate speed without closing the fire-rooms. This benefited the fires, but the twelve large two-cylinder blowing engines used about as much steam as they made.

The longest chase we had was after a swift British steamer that led us about fifty miles and kept the firemen very busy for three hours before our guns reached her. It was a source of deep regret that her papers were regular and she could not be held. Her master, knowing that he had a fast vessel, probably thought it would be sport to give us a chase, though he had nothing to run for. A similar joke, equally unappreciated, was played on the *Oregon* by one of the pernicious newspaper yachts before the battle-ship had been with us long enough to know and avoid the parasites of the fleet.

Conditions in the engine and fire rooms were naturally more exacting and intense when the ship was in action than at other times, closer attention to work being shown, and a desire to excel pervading the whole force. It has been said that the men below are deprived of the excitement of battle, but I found this not to be entirely true. Very few of them were employed every minute, and there was no prohibition against their going up in a moment of rest to get a breath of fresh air and a momentary glimpse of the fight. From them thus, all below were kept informed of

the progress of events, and all were as interested in it as any man on deck. There never was any great excitement, but the men showed in a quiet way that they were nerved for extraordinary exertion and beyond any consideration of fear or personal discomfort.

The most exciting times in the fire rooms were when the ship went off, as she often did, in pursuit of a strange vessel or to investigate a faint stain of smoke on the sky-line. Then all was action and fierce exertion to make steam until the sharp bark of the first gun fired at the stranger gave thrilling notice that the work had not been in vain. Many of our navy firemen are of the fighting race, and it always seemed to me that it was the latent spirit of the grenadier in their Irish blood,—the inherent love of battle and pursuit for the joy of it,—that urged them to unusual exertion on these occasions. I never heard an enlisted man speak of prize money in connection with a chase or capture.

The excitement of the chase was not confined to the fire-rooms, but pervaded the whole company, a knowledge of what was up seeming to spread by magic throughout the ship the moment the engine telegraphs rang for full speed. Even the wardroom sleepers in the middle of a drowsy afternoon would be galvanised into life by the sudden rumble and roar, like a roll of drums, of the great screws underneath working up to their highest speed. The *New York* appeared at her best at these times, as, gray with war-paint and stripped for action, she rushed through the water as though instinct with life, masses of black smoke from her three funnels streaming straight astern like a dread banner of ruin.

A source of annoyance and discomfort in action was powder smoke that the ventilators discharged into the engine and fire rooms in great quantities. This made one's eyes smart and induced coughing that was distressing, the evil being worse below than at the guns where the wind drove the smoke away. When finally dissipated, it left a soapy gray sediment over everything, making a general cleaning-up necessary. The report of guns, particularly those near the open hoods of ventilators, was loud and painful in the engine rooms, the sharp crack of the smaller ones being more ear-splitting than the duller roar of the large guns.

Concussion from much firing of the guns brought an element of anxiety and some danger into the engine-rooms. Glass in bulletin and billboards would be broken and tumble down through the gratings over the engines, accompanied with hard chunks of putty and red lead, dislodged from cracks and holes. Long-lost tools and material would sometimes be brought to light by the falling of chisels, files, bolts, nuts, and other things that had been stowed neatly out of sight on angle irons and ledges overhead to save the trouble of returning them to the tool room. Some of these objects were heavy enough to be dangerous, but the chief anxiety caused by them was the possibility that something might fall upon a vulnerable point in the machinery. As small a thing as a half-inch bolt or a screwdriver might produce a fatal breakdown at a critical moment by getting mixed with the eccentrics or crank-pin connections.

Experience showed that the gun, as well as the ram and the torpedo, may find the engineer at his post. A piece from a shell that struck the *New York* and exploded on the level of the boat bridge came down the main engine-room ventilator and fell at the feet of the writer, several splinters from a boat destroyed by the shell coming with it. No personal danger attended this incident, as the fragment was not larger than a walnut, and fell by gravity, its energy having been expended by hitting objects on deck before it penetrated the ventilator. It showed, however, that armour gratings are not perfect protection against bursting shells. There were similar experiences on other armoured ships. In one case,—on board the *Brooklyn*,—a chief machinist in the engine-room was hit by a piece of copper rotating band from a shell that exploded above the protective grating.

The destructive power of even a small

modern shell, fired at high velocity, cannot be imagined until one has witnessed it. The shell referred to that hit the *New York* was only 15 centimeters in diameter (a little less than 6 inches), but its explosion scattered fragments over a region the whole width of the ship and fully one hundred feet in extent fore and aft; boats, decks, smoke-pipes, and ventilators were marked by holes, big and little, in at least fifty places; a searchlight was totally wrecked, and men were killed and wounded. The one man killed was hit in the back of the head by a fragment not larger than a copper cent, but its velocity was such as to produce penetration and instant death. No wonder that the Spanish crews could not stand to their guns when their ships were being hit several times a minute by missiles of such explosive force.

Familiarity is said to breed contempt, and we found the adage true in war. When the *New York* first went on the Cuban coast we kept steam on all six of the main boilers, five being connected for steaming and the other held in reserve with heavy, banked fires; the after pair of engines could take all the steam that five boilers made with natural draught and drove the ship at the greatest speed ever required.

After a time, ships to chase became rare in those waters while the probability of being attacked became more and more remote. Chiefly to save coal, our original vigilance was somewhat relaxed, and fires were allowed to die out entirely in one boiler, one being kept banked and four connected to the main steam pipes for use. In that condition we spent the first part of the long vigil in front of Santiago harbour after the Spanish ships had taken refuge there. The next backward step, induced by the great difficulty of getting coal at sea, and seemingly warranted by the utter improbability of the enemy coming out, was to connect only three boilers for steaming, with two banked. Afterward, not long before the end came, one of these banked boilers was allowed to die out, leaving three joined for steaming, and one banked, in which condition we were when the Spanish fleet came out.

On the day of the great sea fight the writer had the watch in the engine-room from 8 A. M. to meridian. A few minutes before 9 o'clock the telegraphs began ringing, and soon indicated full speed ahead with both engines. This was a customary proceeding every hour or so, to keep the ship in position, the engines being used from one to perhaps five minutes each time. If any longer movement was intended, it was usual for the officer of the deck to inform the engineer on watch so that the latter could have the fires, necessarily light when lying still so much, built up to meet the demand.

This notice was not sent to me on the morning in question, and we consequently jogged along at less than nine knots speed, with a gradually falling steam pressure, expecting the signal to stop every moment. This was fortunate, as it turned out, as the *New York* did not get as far from her station as she would otherwise.

About 9.15 I sent the cadet who stood watch with me to the berth deck to inspect the auxiliary machinery running there. When he returned he informed me that the ship was on the way to Siboney, he having heard this in the officers' quarters as he passed through. Though unofficial, this was the only information I had, and I sent an order to the water-tenders to work up their fires. At 9.30 the usual call to quarters sounded, and the crew fell in for inspection on the upper deck.

About five minutes later the telegraphs suddenly rung to stop and back one engine, the other continuing ahead; at the same time the wild bugle cry to battle rang out, but that happened so often that I thought little of it until the navigator, in charge on the bridge during quarters, called me up over the telephone with the information that the Spanish ships were coming out of the harbour. My first sensation was one of absolute delight that the event for which we had hoped so long and despaired of ever seeing was to occur; this was followed by a sense of regret, so keen that

it was actual grief, when I realised that the *New York* was off her station.

Now that it is all over, it is easy to see that it was a good thing that the *New York* was off her customary post in front of the Morro. The enemy's fleet was totally destroyed, with a loss to us of but one man; the *New York* is so large and was so conspicuous as flagship that she would have been the target for the whole Spanish fire for several minutes in such easy range that she surely would have been hit and had men killed. As it all transpired, the conduct of the battle could not have been better or more fortunate than it was.

However, there was no time for sentiments of either joy or regret. Our men, in their clean white uniforms, as they had dressed for Sunday inspection, were pouring down the ladders to their stations in engine and fire-rooms, and all the preparations for battle had to be hurried forward. Fires were hauled from the auxiliary boiler on the berth deck and steam and water blown out of that boiler; this was bad for the boiler, but was always done when going into action to guard against the calamity that would follow its being hit by a shot.

Steam was shut off all pipes above the protective deck except the whistle and siren, fires were spread in the banked boiler, hose was connected to several pumps in the engine-rooms for use as a reserve system should the fire-main be cut, and many other things were done within a few minutes, for the men had had much experience and were thoroughly familiar with what had to be done.

One of the assistant engineers, coming to his battle station below, informed me that the enemy's ships were turning westward at high speed, and evidently meant to run rather than fight, he suggesting at the same time that we should have steam on all boilers for a long chase if necessary. I directed him to take charge of the boiler rooms and get up steam on the two dead boilers with all haste, which he did, using assisted draught on them for about an hour. Both these boilers had fresh water in them up to the steaming level, the water being hot in one, as the fires had died out in it only thirty hours before. We had it under pressure and connected for steaming in less than two hours. The other boiler had had no fires in it for about ten days, and took two hours and forty minutes before it was connected to the main steaming system. The official order to start fires in these boilers came after it had been done.

Soon after the first alarm I had time to go on the berth-deck level to inspect the turret engines, as my station for battle required. This gave me the opportunity to go on the upper deck and get my first view of the battle, which was spread out before us like a tragedy on the stage. The spectacle can be described by no other word but glorious, and will live forever in the minds of those who had the rare fortune to see it.

A great cloud of yellowish-white smoke filled the narrow harbour gap that we had watched so long, and rose higher than the Morro and the neighbouring hills. Under it, and partly obscured by it, were the big black hulls of the Spanish ships, steaming swiftly, close together, in line ahead, and glowing with the fire of their guns. Our own ships looked far out and beyond the enemy, and were rather widely scattered. Each was in a cloud of its own smoke, literally blazing with gun fire, the *Iowa* especially looking like a volcano in violent outburst. One thing that impressed me particularly was a great splashing in the water near the Spaniards, showing that many of our projectiles were falling short.

Everything went well in the engine and fire-rooms, and the men exhibited zeal and energy beyond praise. They were kept informed of the progress of events, and entered into the spirit of the occasion with great enthusiasm, realising that it was their fight until they could get the ship within gun reach of the enemy. The forward main engines were heated with steam, their air and circulating pumps started, and all preparations made for using them. I reported them ready to the chief engineer,

and suggested that we stop to couple them up; but the captain, when the chief went to him about it, said that it was not necessary; that we were doing well enough, gaining rapidly on our own ships and on the only one of the enemy still at large,—the *Cristobal Colon*.

At that time our after engines were taking steam from all six main boilers, and were making from 104 to 106 revolutions per minute, or about 17 knots. With another set of main engines and the forced draught system still in reserve we were confident of catching the *Colon*, even if she made her reputed speed. Our men were enthusiastic, and there were plenty of them, the machinery was working beautifully, the coal was fairly good, and it is a matter of regret that we could not have made a speed competition to a finish with her. It was a great surprise when she suddenly gave up the race and turned inshore. Her ending was not creditable to the profession of naval engineering.

Bad as her performance was, it was better than that of the *Maria Teresa* and *Vizcaya*, both ahead of her as they came out, and both passed by her within about half an hour. She also steamed past all the American ships that were west of the Morro, and at one time, about an hour and a half after the fight began, led them by fully six miles. Of these ships, the *Brooklyn* was the only one that was supposed to excel the *Colon* in speed, but she was caught in worse plight than the *New York*. The machinery installation of the two ships is the same, except that in place of one of the big double-ended boilers, the *Brooklyn* had two single-ended ones.

When the Spanish ships came out, the *Brooklyn* had steam on three main boilers connected for use, the others all being dead. The fires in the steaming boilers were not fully spread, and the two after boilers, both double-ended, were deficient in water, requiring them to be run up from the sea. Such good work was done, however, that one of the small boilers was connected for steaming in two hours, and a large one in three hours. The other two boilers were not ready during the chase. Like the *New York*, the *Brooklyn* used only the after set of main engines. In the three hours and forty minutes between the first alarm and the surrender of the *Cristobal Colon* the *New York* gained six miles on her original distance from the *Brooklyn*.

The *Oregon* was the only American ship ready for a full-power performance when the enemy appeared. This is said to have been largely due to the insistence of her chief engineer, Mr. Milligan. She overcame part of the lead gained by the *Colon*, and was the factor that decided the early surrender of that vessel, though theoretically about four knots slower. When the surrender took place she was steaming about three knots faster. The positions of the American ships at various times during the chase, as determined by a board of officers appointed for that purpose, show that the *Oregon* steamed more miles in pursuit than any other vessel except the *New York*, the latter vessel having gained only four miles on her during the time.

Until official reports from the Spanish ships are published we cannot know positively the reasons why they made such a poor showing under steam. In coming out, as they did, under full power, with the knowledge that they were to run, they had a great advantage, taking us unwarned and mostly unprepared. They may, as has been claimed, have been troubled with poor coal, and have had insufficient numbers of men in their fire-rooms, but underlying all their difficulties is their lack of mechanical aptitude. They had despised the mechanical arts and sciences, and by those arts and sciences they fell.

FIG. 1.—THE BURLINGTON & MISSOURI RAILROAD SHOPS AT HAVELOCK, NEB.

AMERICAN LOCOMOTIVE REPAIR SHOPS

By William Forsyth

THE cost of repairs to locomotives is 25 to 30 per cent. of the whole expense for locomotive service, and it amounts to about $1000 (£200) a year per engine. Repairs are classified with reference to the extent of the work which may be required, and are divided usually into four classes after the manner indicated in the following table:—

No. 1, New boiler and general repairs time in shop	75 days
No. 2. New fire-box and general repairs	50 days
No. 3. Resetting tubes and general repairs	35 days
No. 4. Resetting tubes; turning tires and light repairs........	20 days

No. 2, or general repairs cost, depending upon the size of the locomotive, from $2000 to $3500. A heavy eight-wheeled American passenger engine made the following mileage in a term of years in fast passenger service, and cost for repairs in the different years the amounts marked opposite:—

1894—	69,800	miles cost for repairs	....$943	(£189)
1895—	59,600	" " "	1,808	(£361)
1896—	66,700	" " "	1,477	(£295)
6 mos. 1897—	33,690	" " "	 893	(£179)
Total,	234,79		$5,384	(£1,077)

This gives an average of 2.29 cents (1⅛d.) per mile.

A heavy Mogul engine, in fast passenger service, made in five years 290,000 miles, and cost for repairs $15,395 (about £3079), an average of 5.33 cents (2.66d.) per mile. These items will give a general idea of the expense to railroads for keeping locomotives in good working order, and the large amount of money expended in operating their repair shops.

The economy of shop operations depends not only upon the efficiency of the machine tools and the management of labour, but also upon the convenient arrangement of the shops and their equipment with facilities for the proper handling of material. Defects in shop design, causing inconvenient handling of material or movement of workmen, are permanent and cannot be remedied. From the time the raw material is taken in hand until it is erected in the finished

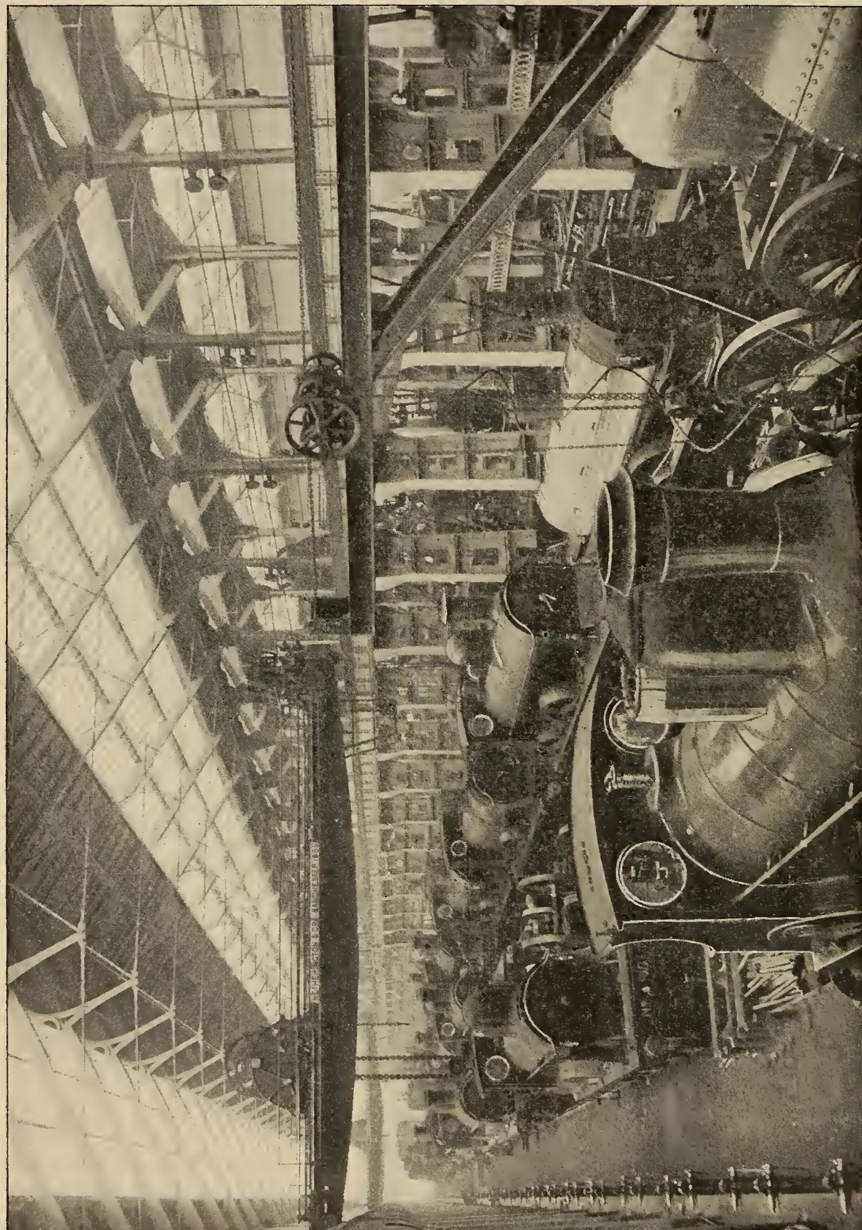


FIG. 2.—THE ERECTING SHOP OF THE LANCASHIRE & YORKSHIRE RAILWAY AT HORWICH, ENGLAND

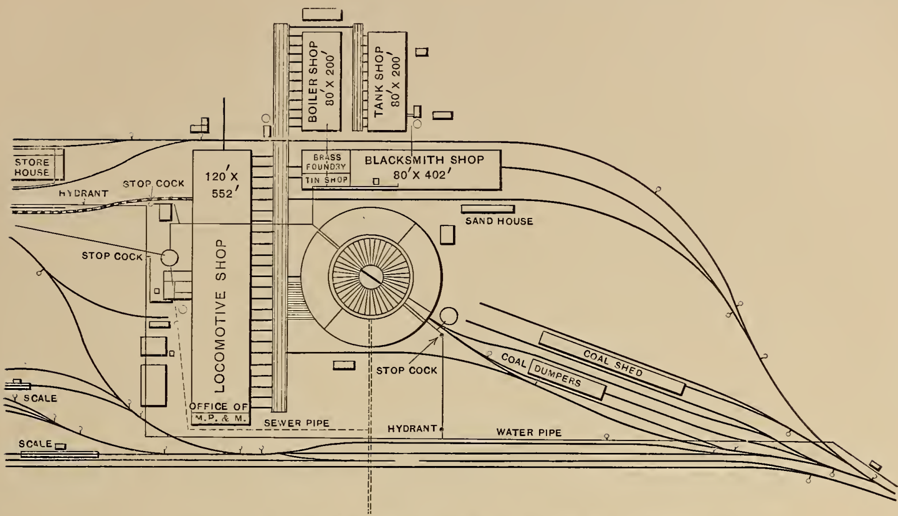


FIG. 3.—THE CHICAGO & NORTHWESTERN R. R. SHOPS AT WEST CHICAGO, ILL.

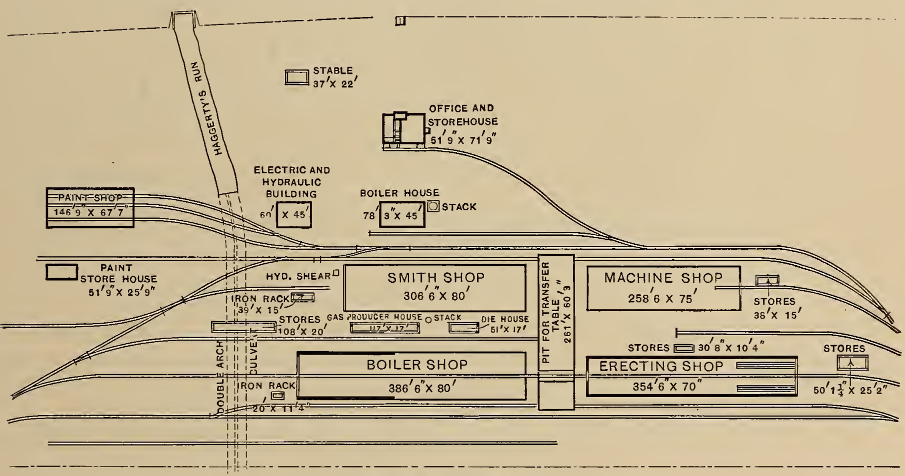


FIG 4.—THE JUNIATA SHOPS AT ALTOONA, PA.

locomotive its movements should be directed to that end.

The plan of a locomotive repair shop is, therefore, an interesting and important problem for every master mechanic and motive power superintendent, and it is thought that the illustration of some representative locomotive repair shops, to show the relative sizes of the different departments and their location with respect to one another, with a brief discussion of the advantages of certain features of design, may be profitable and suggestive to railroad men employed in the mechanical department. The size of a locomotive repair shop is determined by the probable number of engines to be kept in repair, although this is not a very exact measure, as the practice varies on different roads as to the activity of its motive power. It was formerly customary to allow engines in good condition to remain in the roundhouse one-half the time; that is, they were idle while the engineer and fireman slept and rested, a period about equal to the time the engine is in service on the road. Under such condi-

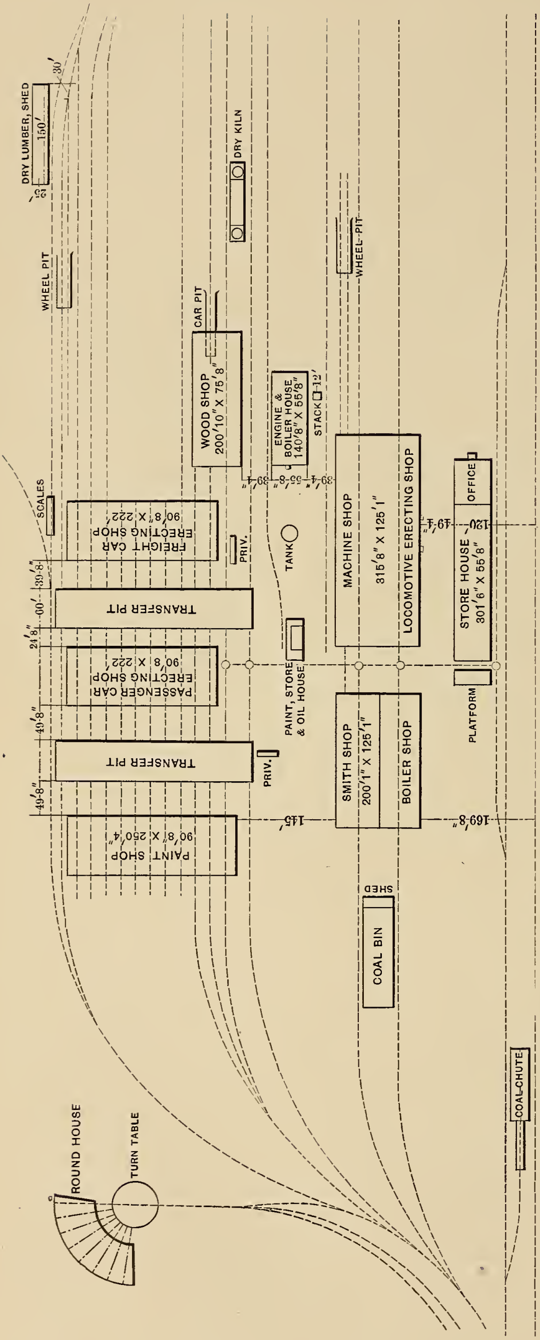


FIG. 5.—THE CHICAGO, BURLINGTON & QUINCY SHOPS, AT WEST BURLINGTON, IA.

tions the engines make a small mileage per month, and the demand upon the repair shop per engine per year is not large.

In recent years, however, it has become the policy of the more progressive roads to increase the mileage rather than the number of engines to provide for increased traffic. By having a larger number of crews, so that one engine has two crews, it may be kept in service day and night, with but a short lay-up at the round-house for inspection and cleaning, and thus the mileage per year is largely increased, and the demand for repairs also.

At present, it may be considered good practice to obtain from freight engines 3500 miles per month, and from passenger engines 7000 miles per month. On some roads as high as 5000 to 6000 miles per month are obtained from freight engines, and 10,000 to 12,000 from passenger engines. With an average of 4000 miles per month, and repairs required every 100,000 miles, each engine would come into the shop every two years, and the yearly capacity of the shop would be equal to one-half the number of engines, and if each one averaged two months in the shop, the capacity of the erecting shop should be $\frac{1}{2} \times \frac{1}{6} = \frac{1}{12}$, or 8 per cent. of the equipment. For 300 engines the erecting shop should have capacity for 24 engines, and for 500, a capacity for 40 engines.

With an erecting shop 65 to 70 feet wide there is room for three longitudinal tracks, with space between wide enough to clear a locomotive suspended from cranes, and passing between rows of locomotives on the three tracks. If we assume that an engine will occupy 36 lineal feet of shop room, and that the two side tracks and one-half the middle track are filled,

the length of shop required for 24 locomotives will be about 350 feet, and for 40 locomotives 570 feet. We thus arrive at the approximate size of the erecting shop for any given equipment, and the table on page 231 shows the size of the machine shop, boiler and smith shops, as compared with the erecting shop as a unit for a number of large repair shops, including the Juniata shops of the Pennsylvania Railroad, which were intended for new work only.

This plant, as built, was calculated to have a capacity of 150 new locomotives per year, and it has produced them at a somewhat greater rate. The Norfolk and Western Railroad has about 425 locomotives, and most of them are now repaired at the Roanoke, Va., shops. The erecting shop there is 64 × 316 feet. The West Burlington shops of the Chicago, Burlington and Quincy Railway have an erecting shop of very nearly the same size,—62½ × 315½ feet,— and will accommodate 22 locomotives. The Burnside shops of the Illinois Central Railway have an erecting shop 80 × 550 feet. This is an example of a shop where the tracks are crosswise of the building, with doors opposite, each leading to a transfer table outside. With a space of 14 feet for each track, this shop should accommodate about 40 locomotives, which is 5½ per cent. of their total equipment.

The last shop mentioned in the table is that of the Lancashire and Yorkshire Railway, at Horwich, England. The erecting shop there is remarkable for its great length, the size being 118 × 1520 feet. The equipment of the road is 1000 locomotives, and at the time the writer visited this shop it contained 100 locomotives undergoing repairs. The interior view of one section of this shop, given in Fig. 2, affords a good idea of the large number of engines in it.

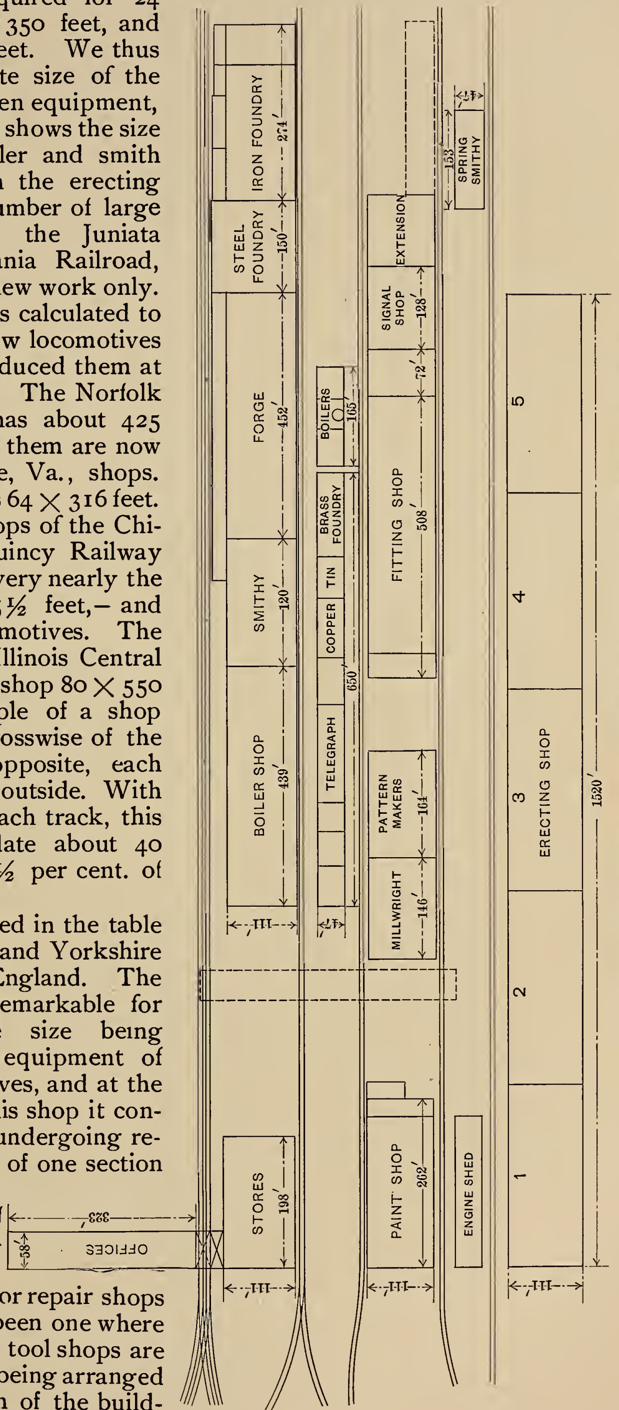


FIG. 6.—PLAN OF THE HORWICH SHOPS OF THE LANCASHIRE & YORKSHIRE RAILWAY

The prevailing design for repair shops in the United States has been one where the erecting and machine tool shops are in one building, the tools being arranged along one-half the length of the building, and the erecting shop, with tracks

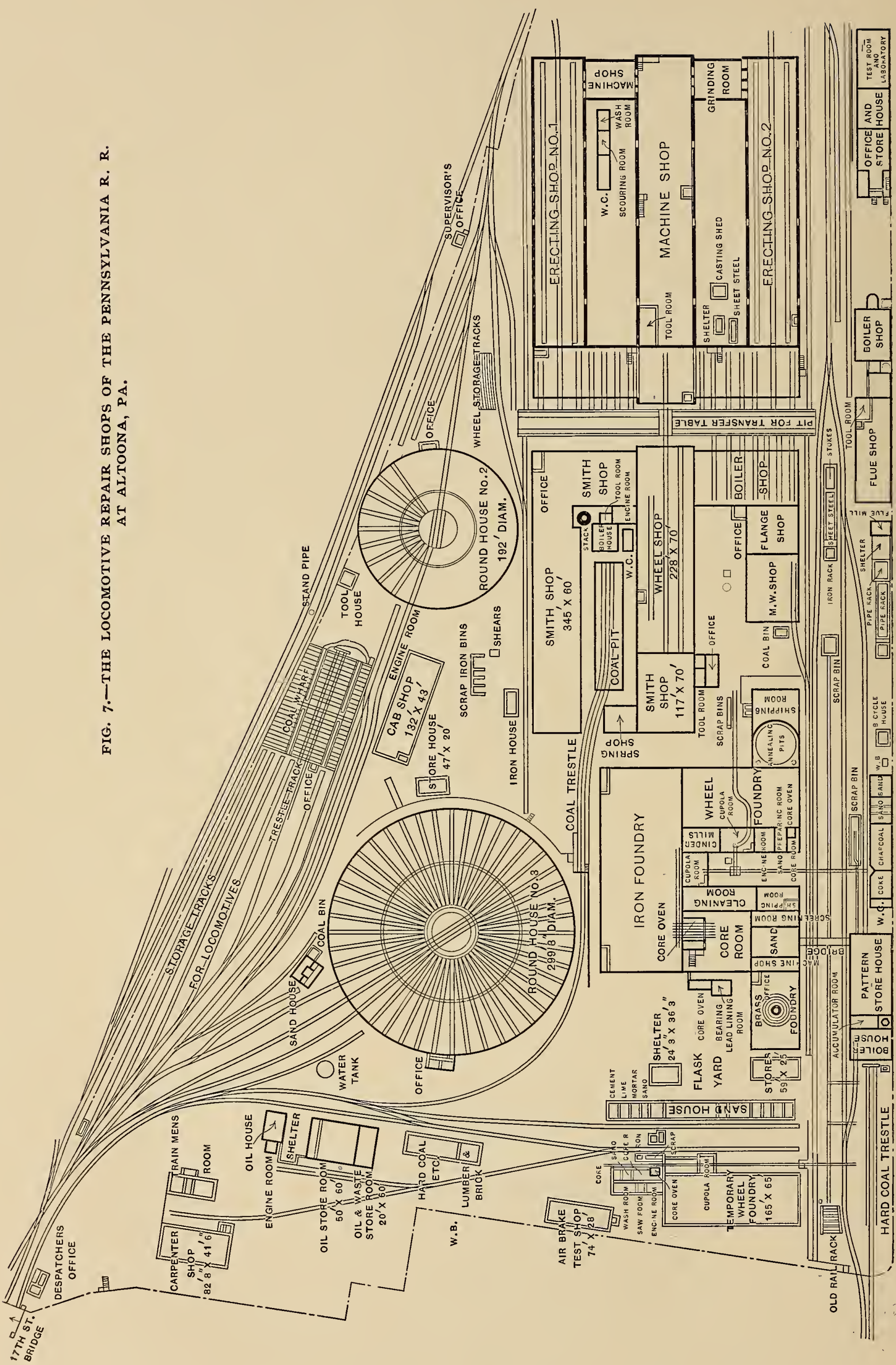


FIG. 7.—THE LOCOMOTIVE REPAIR SHOPS OF THE PENNSYLVANIA R. R. AT ALTOONA, PA.

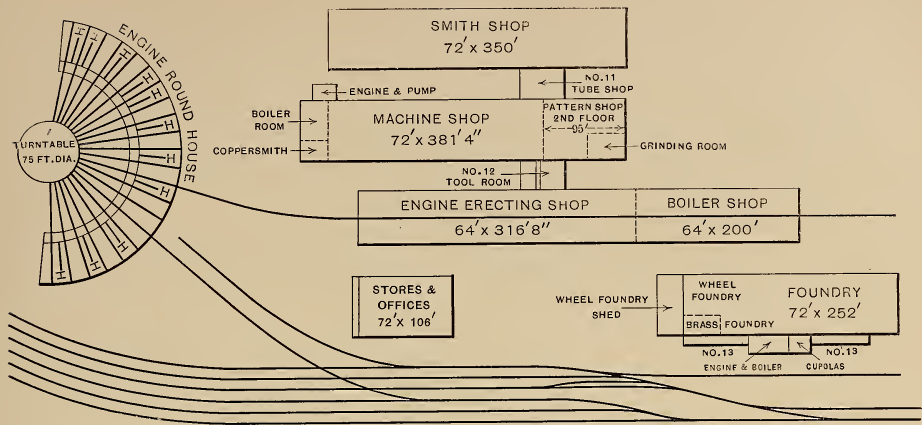


FIG. 8.—THE NORFOLK & WESTERN R. R. SHOPS AT ROANOKE, VA.

at right angles to the length, on the other side. This plan requires a transfer table, with doors opening opposite each cross track, as already mentioned in connection with the Burnside shop. It is also illustrated by the plan of the Northwestern shops at West Chicago, Fig. 3, and the Grant Locomotive Works, Fig. 16.

Erecting shops with longitudinal tracks and overhead cranes, which dispense with transfer tables, have also been built in connection with the machine tool shop in the same building, as in the case of the Chicago, Burlington and Quincy shops at West Burlington, Ia., Fig. 5. They have also occupied the entire building, notably in the case of the Horwich shops, shown in plan in Fig. 6; the Juniata shops, Fig. 4; and the Altoona shops, Fig. 7.

The erecting shop has also been combined with the boiler shop in one long building, as illustrated by the Roanoke shops, Fig. 8, and the new Boston and Maine shops, Fig. 10, and in a plan made by the writer, Fig. 9. In these latter plans the boiler shop is separated from the erecting department by a thin partition, sufficient to prevent the noise of riveting and chipping or calking from being heard in the adjoining shop. This appears to be the only objection to such an arrangement, and the plan has several advantages.

First. It is the obvious and natural arrangement to so locate the boiler shop that the finished boilers pass di-

Comparative Sizes of Locomotive Repair Shops.

Kind of Shop.	P. R. R. Juniata Shops. 38¾ Acres of Land. Yard, 775′ × 2150′.				Norfolk & Western Shops. 20 Acres of Land (Yard, 600′ × 1450′. 2.65 Acres Roofed Area.		C. B. & Q. R. R. West Burlingt'n Shops. 40 Acres of Land. Yard, 800′ × 2200′. 2.04 Acres Roofed Area.		Illinois Central R. R. Burnside Shop. 160 Acres. 3.4 Acres Under Roof.		Lancashire & Yorkshire. Horwich Shops. 85 Acres Land. 13½ Acres Covered.	
	Present Shops. Total Roofed Area, 2¾ Acres.		Extended Shops Total Roofed Area, 5½ Acres.									
	Size of Shop.	Percentage of Erecting Shop.	Size of Shop.	Percentage of Erecting Shop.	Size of Shop.	Percentage of Erecting Shop.	Size of Shop.	Percentage of Erecting Shop.	Size of Shop.	Percentage of Erecting Shop.	Size of Shop.	Percentage of Erecting Shop.
Erecting	70′ × 354½′	100	70′ × 578½′	100	64′ × 316′	100	62½′315½′	100	80′ × 550′	100	118 × 1,520	10.0
Machine	75′ × 254½′	80	75′ × 418½′	80	72′ × 381′	135	62½′315½′	100	80′ × 550′	100	111 × 400	24.8
Boiler	80′ × 386½′	130	80′ × 628½′	124	64′ × 200′	63	62½′ × 200′	63	100′ × 200′	45	111 × 364	22.5
Smith	80′ × 308½′	100	80′ × 530½′	103	72′ × ′350	124	62½′ × 200′	63	110′ × 380′	95	111 × 210	13.0

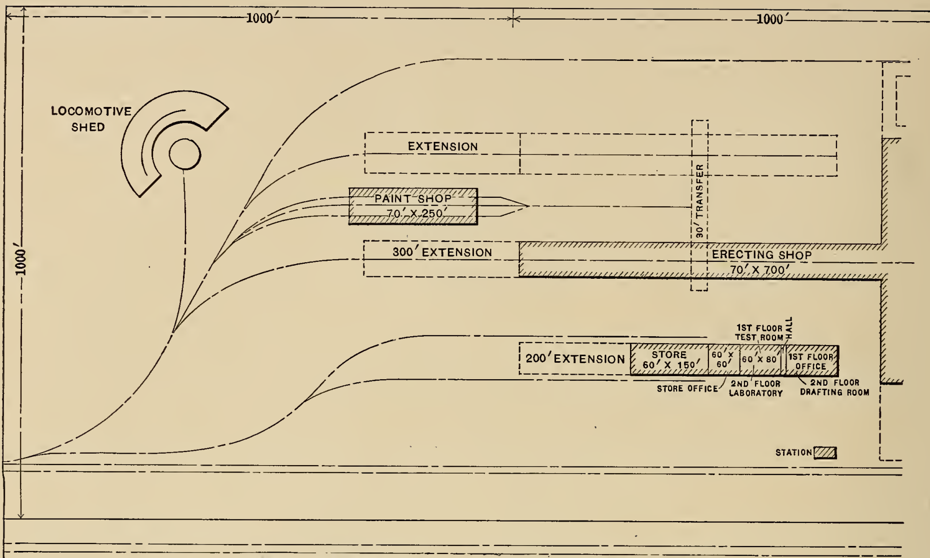


FIG. 9.—HALF-PLAN FOR A LOCOMOTIVE REPAIR SHOP

rectly and most easily to the erecting shop.

Second. No transfer table nor switching engine are required for communication between the principal departments.

Third. No outdoor work is necessary in winter, and no outside doors are opened for the transfer from one shop to the other.

Fourth. There is a large saving in the cost of the building, by dispensing with two large brick gables with their windows and doors.

A fifth advantage is that boilermakers and their tools are often required on repairs in the erecting shop, and by this plan they are most convenient to their work.

We may next consider the advantages or disadvantages of the relative positions of the machine and erecting shops in the plans illustrated. For shops engaged almost exclusively on repair work, it is most convenient to have the machine shop in the same building with the erecting shop. For building new locomotives this is not so important, as the work may be organised so that there is a natural flow of finished machinery to the erecting shop; but in the case of repairs there would be a constant flow back and forth from one building to the other, causing considerable waste of time.

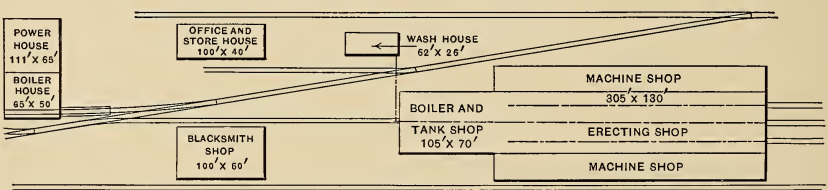


FIG. 10.—THE BOSTON & MAINE R. R. SHOPS AT CONCORD, N. H.

In the case of a shop like that at Roanoke, or the Juniata shop, engaged upon new work and repairs, it is a question which might be profitably discussed as to whether it would have been more convenient to have had the boiler shop or the machine shop in the same building with the erecting shop.

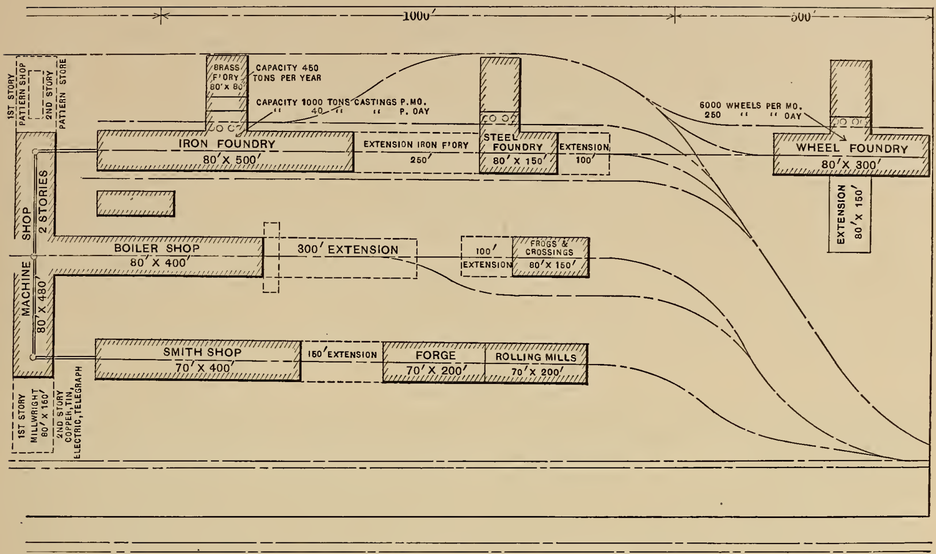


FIG. 9.—HALF-PLAN FOR A LOCOMOTIVE REPAIR SHOP

In thus studying the plans for locomotive repair shops and their relations to one another, to arrive at the most convenient arrangement it may be suggested that it is possible to have both boiler and machine shop in the same building with the erecting shop, and so arranged that the work will have the previously mentioned natural flow from each department where details are made to that where they are assembled on the finished engine. Such a plan is shown in Fig. 9, where the main shop building is in the form of a cross, the erecting shop and boiler shop in a straight line, with through tracks, and the machine shop at the centre and at right angles to the erecting shop. It will be noticed that the iron foundry is near one end of the machine shop and the smith shop near the other.

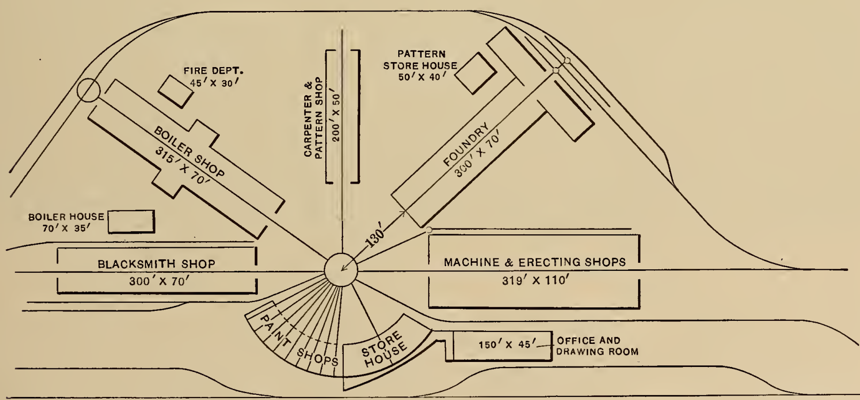


FIG. 11.—PROPOSED PLAN FOR THE WEST SHORE R. R. REPAIR SHOPS AT FRANKFORT, N. Y.

It is intended that the tools for finishing castings shall be located near the foundry and those for forging near the smith shop. While this cannot be done in all cases and with small pieces, yet

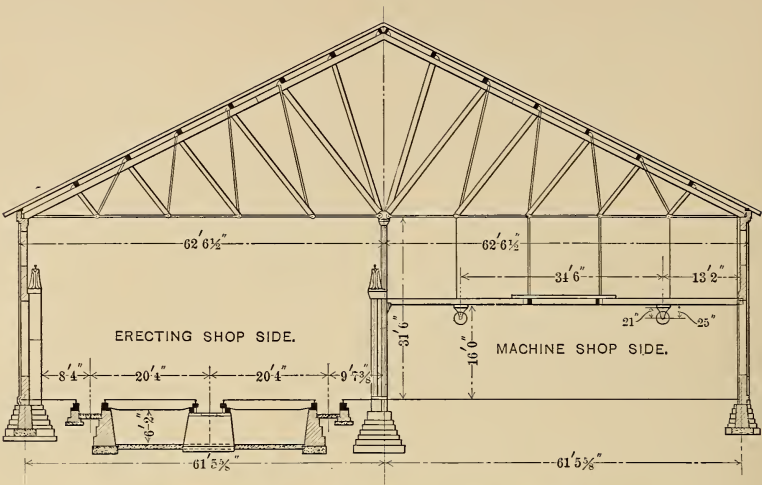


FIG. 12.—CROSS SECTION OF THE C. B. & Q. SHOPS AT WEST BURLINGTON, IA.

with the larger or heavy pieces, requiring most labour in handling, it can be carried out. The tools for planing and boring cylinders, driving wheel lathes, tools for boring and planing driving boxes, wedges and shoes and for finishing eccentric straps, could be at the end of the shop near the foundry. The frame planers and slotters, axle lathes, link motion and rod planers could be at the end next the smith shop. The bolt and screw machines and brass lathes, shaping machines and other light machinery could be in galleries, forming a second story of the machine shop.

The boiler and erecting shops are necessarily high buildings, and in order to make the roof lines intersect properly and be symmetrical, the machine shop should be of the same height, and can thus be a two-story building. The advantages of this plan, so far as the buildings are concerned, are the same as those claimed for the combined boiler and erecting shop, but with the additional economy of saving four gable ends and having so large an amount of work under the same roof, and avoiding all outdoor communication between buildings, and open doors in winter time.

The plan concentrates the three departments required for locomotive repairs from the time of the original construction of the building and admits of the extension of each, while shops built on the longitudinal plan are often placed far apart for this purpose, and are oper-

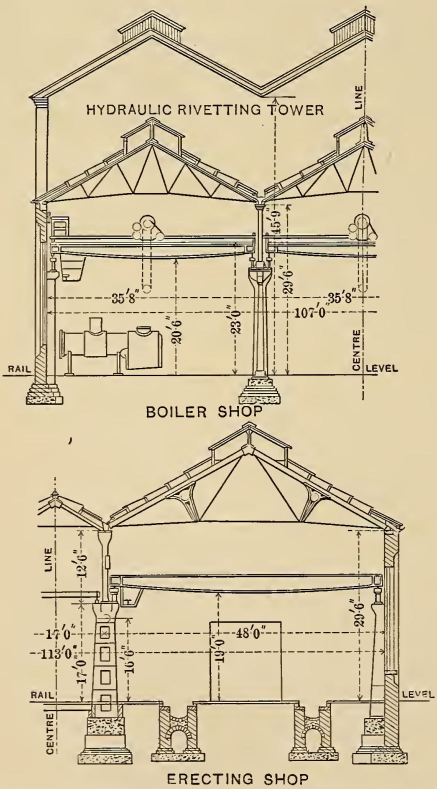


FIG. 13.—CROSS SECTIONS OF THE HORWICH SHOPS

ated at great inconvenience for many years before the gaps are filled in.

A good illustration, showing how widely apart the different methods of connecting the different buildings comprising a locomotive repair shop may be, is the plan once proposed for the main repair shops of the West Shore Railroad, and partly carried out in the shops of that line at Frankfort, N. Y., Fig. 11. In this plan the buildings were arranged radially, having a turntable at the centre. If the turntable and the space between it and the buildings were inclosed in a circular building with a grand dome, the scheme would carry out to its ultimate conclusion the elementary idea suggested by the cross plan in Fig. 9, already described.

Where power traveling-cranes are employed in erecting and boiler shops the height of the walls must be about 30 feet in the clear inside. If the erecting shop and machine shop are side by side in the same building, as at Burnside, West Burlington and Havelock, 30 feet are higher than necessary for the machine shop, and in the shops mentioned there is considerable waste room over the machine tools. For this reason a gallery for the light tools in a second story of the machine shop has been suggested. A cross section of the West Burlington erecting and machine shops is shown in Fig. 12, and sections of the Horwich erecting and boiler shops, with cranes and riveting towers, are shown in Fig. 13.

At West Burlington the two shops have a single gable at each end; at Burnside and Havelock there are two sets of trusses, and a gutter at the centre, longitudinally. At Havelock, Nebraska, the main buildings all have hipped roofs and no peaked gables, as shown in Fig. 1, on the opening page of this article. The large building to the left is the combined machine and erecting shop, and the boiler shop is at the extreme right. Fig. 14 shows an interior view of the West Burlington erection shop, with longitudinal tracks and overhead crane.

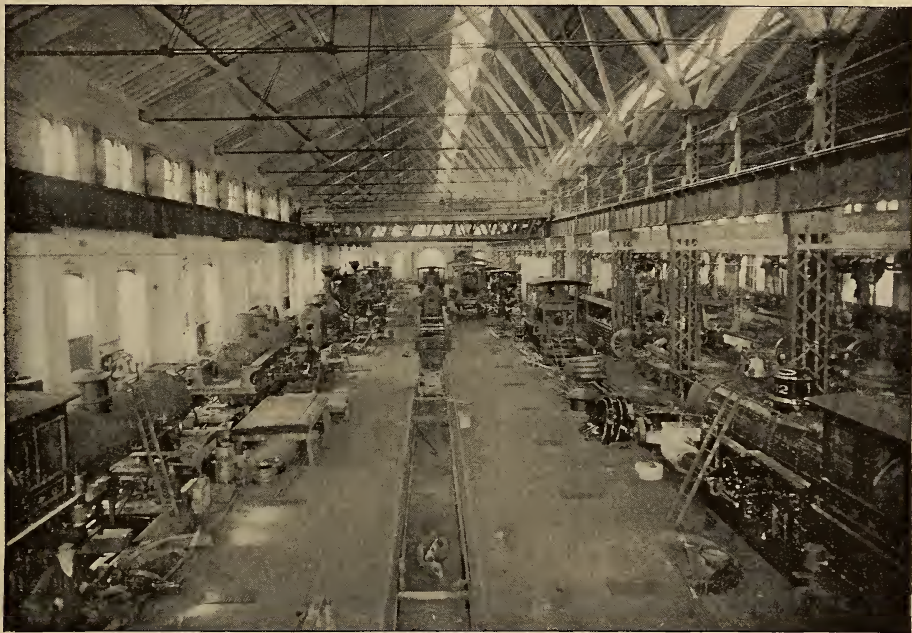


FIG. 14.—THE CHICAGO, BURLINGTON & QUINCY RAILROAD SHOPS AT WEST BURLINGTON, IA.

A very good plan for the roof arrangement and crane space is shown in Fig. 15, which represents a cross sec-

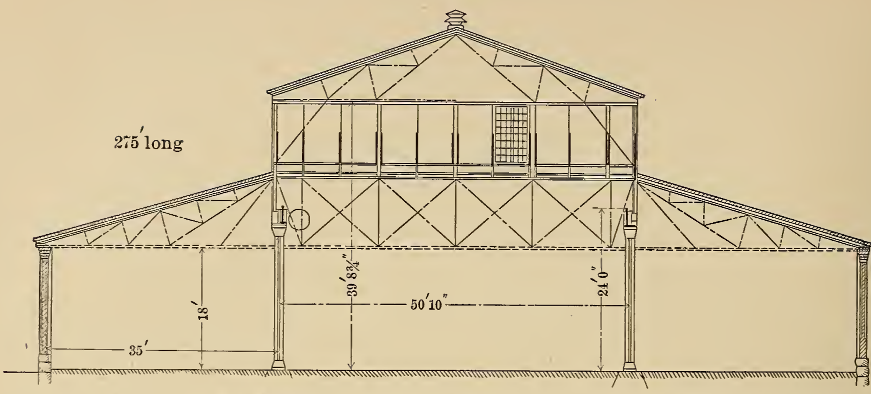


FIG. 15.—SECTION OF BOILER SHOP OF THE PITTSBURGH LOCOMOTIVE WORKS. PITTSBURGH, PA

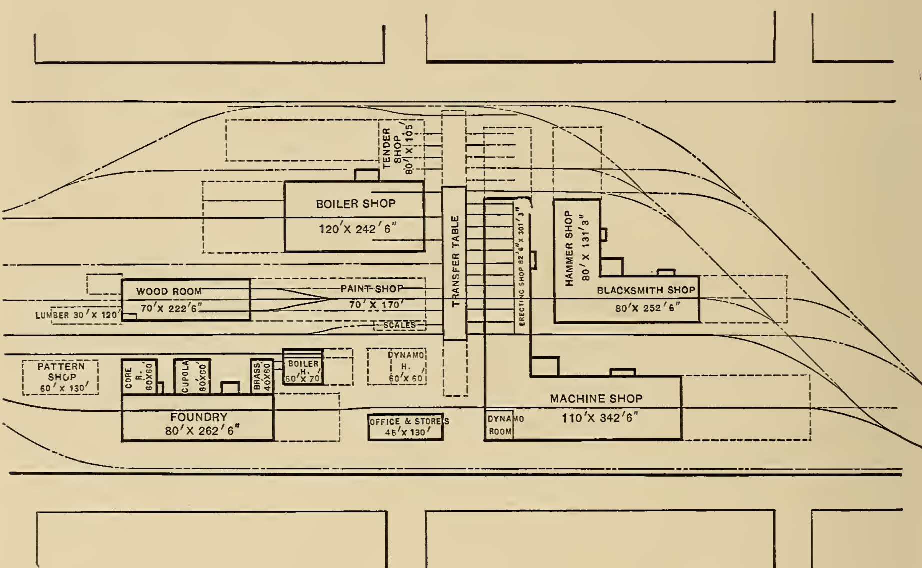


FIG. 16.—PLAN OF THE GRANT LOCOMOTIVE WORKS AT CICERO, ILL.

tion of the boiler shop of the Pittsburgh Locomotive Works. This section would also be a good one for a machine shop. The central portion has a high story with crane for handling boilers and other heavy work. In the low side wings the lighter tank work occupies one side and the power tools for boiler work the other side. The shop is well lighted and ventilated, costs less, and is more easily heated than a building of equivalent floor area and high side walls.

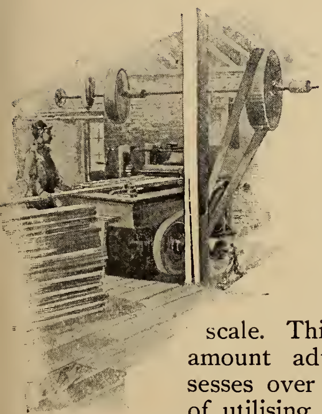
The new shops of the Boston and Maine Railroad at Concord, N. H., have the machine and erecting shops built with a similar cross section, the boiler shop being an extension of the high-story part of the machine shop (see Fig. 10). In this plan the machine tool department is divided, and occupies the two side wings of the high erecting shop. The cranes from the machine shop can run directly into the boiler shop. The erecting shop, machine tools and boiler shop are thus concentrated in one building. If the side wings forming the machine shop had been continued alongside the boiler

shop, they would have provided an excellent place for boiler-shop tools on one side and tank work on the other side. In the Boston and Maine shop are realised, for the first time in the United States, as far as is known to the writer, that which he regards as the ideal conditions for a locomotive repair shop where large power cranes are used.

It has been the purpose of this article to show the advantages of such a plan, or others, where the principal departments required for locomotive repairs are arranged in one building.

THE ELECTRIC MOTOR FOR SMALL INDUSTRIAL PURPOSES

By Alfred H. Gibbings, M. Inst. E. E., City Electrical Engineer of Bradford, England



THE electric motor is rapidly becoming the most favoured medium for the transformation and transmission of energy for all industrial operations, whether on a large or small scale. This is due to the paramount advantages it possesses over any other method of utilising potential energy. These advantages, as stated by the writer in a paper recently read before the British Association for the Advancement of Science, while well known to electrical engineers, are indifferently appreciated by a large number of mechanical engineers, and almost unknown by the general manufacturer and tradesman. To the last of these three, the general manufacturer and tradesman who is using machinery driven at present by steam or water-power, the electric motor must in the days to come prove of exceptional value; and yet, strangely enough, very little effort has hitherto been made, either by the motor maker or by the managers of electricity supply undertakings, to open up this very wide and lucrative field of enterprise.

It is not necessary to enumerate here the many excellent and distinctive features which the electric motor possesses. The intention here is rather to consider the reasons why its application up to the present time has been confined to a few special trades and manufactures. We are familiar, for instance, with electrically driven pumps, electric hoists and cranes, electrically driven machine tools, and electric power transmission in works,—cases in which the generation, transformation, and application occur practically under one roof. Many manufacturers and constructional engineers, wisely and readily incurring additional capital outlay with the object of securing more economical production, have adopted electric motors, which do not entail the use of endless and power-absorbing shafting and countershafting. As yet, however, it cannot be said that the electric motor is in general use, or scarcely other than just past the threshold of its future domain.

The smaller producer and tradesman, to whom motive power in some form or other is essential, and who feels more acutely than his larger *confrère* the effects of competition, has, in the great majority of cases, still to put up with very much more cumbersome and very much less efficient means of power production. Almost every town with any pretension to size and importance has its own large staple industries, as well as many minor industries and busi-

nesses, requiring the use of other power than hand power. There are also some handicrafts which are, at present, unavoidably confined to hand power, because steam, gas, oil, and hydraulic power are each and all inapplicable. There can be little doubt that the electric motor would be welcomed and readily adopted in these cases if only its simplicity and adaptability were known and understood. Appended is a somewhat full, though by no means exhaustive, list of these trades:—

Acid manufacturers, aerated water manufacturers, agricultural implement makers, automatic electric signs, back and vat makers, bag makers, aerated bread makers, basket makers, bicycle makers and repairers, boilermakers, bookbinders, boot makers, boot polishing, bottle cleaners, bottle makers, box makers, brass finishers, brush makers, cabinetmakers, carpenters, carpet beaters, coach builders, coffee grinders, coopers, cutlers, cranes, dairymen, dentists, engineering workshops, engravers, fans for ventilating and other purposes, forage cutters, forced draught, founders, grain elevators, hoists, hair-brushing machinery, laundries, lifts, lithographers, millwrights, musical instrument makers, oil refiners, opticians, organ builders, organ blowing, packing-case makers, paper makers, pianoforte makers, picture-frame makers, presses, printing machinery, pumping, racket makers, rope makers, sack makers, saddles, sausage makers, saw makers, saw-mills, scientific instrument makers, seed crushers, sewing machines, shop fitters, smallware manufacturers, smelters, smiths, snuff manufacturers, soap makers, stick makers, stuff manufacturers, sugar refiners, surgical instrument makers, theatrical machinery, timber merchants, tinplate workers, tobacco cutters, tool makers, toy makers, turners, umbrella makers, undertakers, watch makers, wire drawers and workers, zinc workers, etc. Other special and local industries which can be placed in the same category, will occur without enumeration.

The advantages of driving electrically in some of these cases are of a very distinctive character, and it will be well to consider briefly one or two prominent examples.

Boiler Makers.—The practice of drilling all rivet holes in boilers with the overlapping plates *in situ* is an operation which is much more rapidly, readily, and economically performed if the drilling machines can be brought to the work instead of taking the shells to a fixed machine tool and there adjusting them for every fresh set of holes to be drilled.

Book Binders, Boot Makers, Cutlers, Presses, Saddlers, Saw Mills, Smiths, etc.—These trades are instances in which several machines are frequently employed, but of which intermittent use only is required. By any method of driving other than by electricity, it is incumbent to employ lines of shafting and countershafting, and to keep these in continual motion in order to use any one machine when required. In such cases, by direct coupling to the machine to be driven, and by its unequalled facility for starting and stopping, the electric motor has unique and all-important advantages.

Letterpress and Lithographic Printing.—This class of machinery has been successfully operated for upwards of two years by electric motors applied direct to the main driving shaft of the machine or by toothed gearing. Since the first attempts were made, many improvements have been introduced, until, at the present time, nearly all the leading houses in the trade have either adopted the system of single machine driving in its entirety, or some such modification of it as best seems to suit their particular methods of working. It is doubtful if printers realise the immense loss that occurs by the old method of driving. Wherever the system of shafting and belts is used to transmit the energy generated by the driving engine there is a great loss of power; not only so, but a mass of machinery and gearing has to be kept wastefully running whilst possibly only one or two machines may be utilised. In one case where tests were made it was found that the shafting and belts absorbed 56 per

cent. of the actual power generated by the engine. In this industry the extremely steady and even motion imparted by the rotary action of the electric motor is also an important feature.

Cranes and Hoists.—In almost every town there are warehouse and other cranes, and passenger and goods hoists, in general use. The advantages of the electric motor for these purposes are (1) the possibility of placing the motor close up to its work; (2) direct coupling or reduction gearing of high efficiency; and (3) the economy resulting from the power used being practically proportionate to the work done.

There is no need to give further examples in detail. The application of ordinary mechanical tests for efficiency, and the experience already obtained by the substitution of electric motors for other methods of power production, have proved beyond doubt its exceeding adaptability and superiority. Notwithstanding all this, however, many obstacles yet remain to hinder its general adoption by what may be termed the commonalty of the manufacturing world, and among the principal may be mentioned the following:—

1. The extreme aversion to innovations which characterises the industrial world, in Great Britain especially.

2. The existence of other motors in good working condition.

3. The unsuitability of alternating currents of electricity for motors where the power required exceeds 2 H. P. or 3 H. P

4. The want of capital to lay out in new machinery; and

5. The want of confidence in the electric motor by the non-technical manufacturer.

The first and second points do not require any further commentary or elucidation, and the writer would, therefore, dismiss them without more observation. With regard to the third point, it is much to be regretted that he alternating current motor is not yet apab e of doing the same work as a ontinuous-current motor. The energy equired to operate either type must, of course, be derived from some source,—usually a steam dynamo,—from which distribution mains carry the current in any direction; and as this is the most efficient method known of transmitting energy, and the motor the most efficient medium for transforming it into useful work, the principle has been applied in the workshop as well as for public supply. There is no need to dwell upon the advantages of the centralisation of steam power, nor upon the universally admitted fact that electricity for power purposes can be supplied from public lighting mains at a very low cost. But in addition to these there is one equally important advantage of deriving power from public mains from the user's point of view,—I refer to the actual resultant taken on the average of the varying loads, which is characteristic of the electric motor, and the facility for instantaneously switching "on" and "off" as required.

As to the want of confidence of the small power user in the electric motor,—that is soon overcome. It is gratifying to be able to state that several consumers in Bradford who originally applied on the hire system (which is practised there with much satisfaction), and at the time with much trepidation and many inquiries, have since decided to purchase the motors outright. The table on the next page has been compiled from replies to an inquiry which the writer made recently of each municipal electrical engineer where the continuous-current system has been adopted, and from it may be gathered the extent to which electric motors driven from electric lighting mains have been employed. The figures given are up to the end of 1897.

The writer has endeavoured in this paper to present briefly the outlines only of a method of extending the adoption of electric motive power by the general manufacturing community. Those who have the management of public electricity supply undertakings know full well the value of the electric motor as a factor in the reduction of the working costs, which is also the principal argument for the combined working under

one roof of electric lighting and electric tramway systems.

But there are other and probably greater effects which the electric motor will produce with its more complete adoption in the near future,—the writer refers to the beneficial effects upon the trade and productions of the country, and the hygienic and social effect on the community generally. In the first of these aspects it is possible to foresee the revival once more of a number of small and independent industries, such as existed, but under very different conditions, in former years. The possibilities are already being grasped by the artisan in France, Germany, Switzerland, and the United States. By the aid of the electric motor he begins to find that he can at least hold his own in competing with immense manufacturing concerns and combinations; he has a practically unlimited available power at his own door,—which is a great boon to the artisan, and one which offers him an inducement to become his own master.

TABLE GIVING NUMBER OF ELECTRIC MOTORS DRIVEN FROM ELECTRIC LIGHT MAINS IN DIFFERENT TOWNS

Town.	Population.	Number of motors supplied.	Total H.P. of motors.
Aberdeen	140,000	14	65
Bradford	231.260	119	470
Brighton	122,310	100	Not given
Belfast	320,000	Not given	165
Birkenhead	110 000	4	15
Bury	63,000	5	12
Blackpool	40,000	7	7
Burnley	90,000	8	32
Chester	37,100	20	70
Dewsbury	29,847	4	16½
Dundee	169,000	15	20
Edinburgh	295,000	167	343
Glasgow	750,000	37	131
Hull	213,000	14	46
Lancaster	38.224	28	80
Liverpool	641,063	57	152
Manchester	505,368	257	696
Norwich	101,000	61	120
Nottingham	213,877	18	50
Oldham	148,000	11	60
Southampton	90,000	18	23
Shoreditch	124,000	31	434
Sunderland	147,000	23	240
Wolverhampton	92,000	2	3
Whitehaven	20.000	--	--
Walsall	72,000	7	13½

In a very small and limited degree the gas engine has already accomplished something in this direction, but its many imperfections, its cost, and the fact that it has never been available on the hire system, have kept it more or less in the background. The effect of hiring-out electric motors, which, as already stated, is being practised extensively at Bradford, is thus mutually advantageous, and its natural tendency is to create fresh demands; in fact, the municipality which includes this scheme in its electric light undertaking offers a great inducement to the influx and establishment of new industries within its area.

With a more complete return to a multiplicity of industrial operations, there may also revive some neglected trades. From an hygienic point of view, the electric motor is far and away the best; it is cleanly in its working, gives off no deleterious gases, and displaces the boiler and smoky chimney. One of the ultimate results must also be the raising of the status of the working part of the community. By becoming his own master the artisan gains self-respect, becomes more resourceful, and therefore a more important member of society; and the more intelligent interest which he will display in his business must appreciably affect the general welfare of the country.

Current Topics

To what extent electric railways have been developed in the United States, where, admittedly, they have prospered in a manner unparalleled elsewhere, is shown in a short chapter of statistics given in the annual report for 1897 of the United States Commissioner of Patents. The first electric street railway in the United States was put in operation only a little more than ten years ago. In 1880, of the 2050 road miles of street railway in the country, nearly all employed animal power. Electric power had not yet come into use, but a few miles of lines were operated by steam and by cable. The total number of persons then employed on American street railways was a few hundred short of 12,000. Ten years later, in 1890, the United States Census gave the number of street railway employees as 37,434, and at the close of that year the total mileage of street railways all over the country was given as 8123 track miles, on 5661 of which horses were used, while the remaining 2462 miles were worked mainly by electric and by cable power. The capital invested in these roads was $211,277,793, and 71,000 persons were employed on them. In 1894 the total mileage was 12,527, of which 7470 was electric. The capital invested was $648,330,755, of which $423,493,219 were invested in electric railways. One hundred and ten thousand persons were employed on street railways in that year. In 1896 the mileage had increased to 14,470, of which 12,133 miles were electric. The capital invested was $784,813,781, and the number of persons employed was not less than 140,000. The total mileage of electric railways in the United States up to October of 1897 was 13,765 miles, out of a total mileage of 15,718, and of these but 947 miles were horse-car lines. The total capital invested was $846,131,691, and the number of employees may be safely estimated at not less than 166,000.

Among the several other industries of which the report in question makes mention is the manufacture of type-writers and type-writer supplies. There was no report for this industry in the United States Census of 1880. In 1890 thirty establishments were reported employing 1735 workmen and producing an output valued at $3,630,126. Since that year the industry has grown very largely in the number of workmen employed and the value of the product. In 1893 a single company employed

2300 workmen. The exports of type-writing machines and parts for 1897 amounted in value to $1,566,916. There is no reliable statement available as to the number of type-writing machines in use. It was estimated in 1895 that there were then not less than 400,000. One firm engaged in this industry published a statement more than a year ago that in thirty-four office buildings in New York City 3426 type-writers were then in use. Agencies for the sale of type-writers, dealers in type-writer supplies, and schools for teaching the use of the type-writer are found in every city and large town. The great industrial value of the type-writer has been, however, in the employment it has afforded, particularly to women. A bulletin of the Bureau of Education gives the number of schools teaching the use of the type-writer and its necessary accompaniment, stenography, in 1890 as 1081, with 57,375 pupils, nearly all of them women. The census of 1890 reported that 33,418 persons were employed in the United States as stenographers and type-writers, of which 21,270 were women, while in 1870 the census reported only 154 shorthand writers in the United States, of which but seven were women.

To hold down to a lecture platform a light iron object by means of an electro-magnet underneath, out of sight, and thus appear to multiply its weight many times over at will,—to make it impossible even to lift the object in question, providing the magnet be powerful enough,—is an old conjurers' trick which has served on many occasions to mystify the public. Its principle, however, has been applied to several more useful purposes, and one of these, of recent date, is embodied in a magnetic chuck for miscellaneous work, for surface grinding principally, but adapted also for the planer or the lathe The magnetic effect in this chuck is produced by an electric current circulating in a coil in the interior of the device, and as this coil is wound, preferably, for 110 volts, the needed current can be taken from any regular electric lighting main in or about a shop. The convenience of the device, especially for small work, is so obvious that it need not be emphasised, but any one more particularly interested will find its good points detailed in a leaflet published by the maker, Mr. O. S. Walker, of Worcester, Mass.

A MAGNETIC holder for an electric incandescent lamp, brought out by Messrs. Jenkins Brothers, of New York City, is another electric shop convenience which, no doubt, will be quick to commend itself. The holder is simply a lamp socket containing a small electro-magnet which will make the whole contrivance stick to any piece of iron or steel with which it may be brought in contact. The coil through which the magnet is energised is within the base of the holder, and the lamp current supplying the energy passes through it on its way to the lamp. In machine and boiler shops, in engine and boiler rooms aboard ship, in fact, wherever light is needed for machine work, the contrivance ought to prove a convenience of the first order.

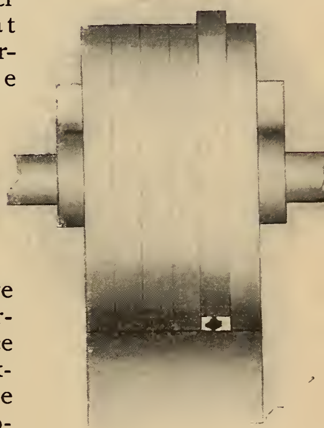
THE end of this century, which is now near at hand, will, in the estimation of even those who are deeply interested in wrought iron, see the end of wrought iron as a distinctive designation, except, perhaps, in the case of Swedish iron or some other high-priced iron specialty. Ordinary bar iron, says *The Iron Age*, apropos of this, will have completely disappeared from the trade. It is becoming increasingly difficult to secure material from which to manufacture genuine bar iron. Scrap has long been the chief dependence of the bar iron manufacturer, who is prohibited by its cost from using puddled iron except for those who insist upon having muck bar iron without regard to price. But the great stocks of scrap iron are nearing exhaustion, iron rails are becoming a

scarce commodity, and a new supply of cheap material for iron rolling mills is out of the question. It is almost an impossibility now for an expert scrap dealer to detect the difference between wrought iron and soft steel in the old material offered him, and a guarantee that any lot of wrought scrap contains no steel is out of the question. Busheled scrap for common bar iron may almost safely be said to contain steel to some extent. And so much more steel is now being consumed than wrought iron that the production of steel scrap is increasing at a rate so rapid that wrought scrap will very shortly be steel principally.

A SYSTEM of sectional cushioned ore-crushing rolls, described at one of the recent meetings of the American Institute of Mining Engineers by Mr. J. W. Pinder, seems admirably adapted to overcome one very annoying trouble and source of expense with the common crushing rolls as now operated in ordinary plants. With these it is almost impossible, economically, to regulate the first operation of preparing the ores for the rolls so that any approach to a uniform size may be obtained. Owing to this unevenness in size it is always necessary to pass and repass the same material several times through the machine in order to obtain a uniform result. As the ore is fed into the rolls, when the larger pieces are clutched, and the pressure begins to bear upon them, the first strain on the springs tends to separate the rolls as shown in the little sketch in this column, until the crushing-point, or point of greatest resistance, is reached before the pieces are actually crushed. In this way, especially in crushing hard ores, the rolls are forced apart as much as 60 to 80 per cent. of the time. This parting is not infrequently as much as half an inch and more. By far the greater part of the material, being fine when it reaches the machine, has a tendency to pass through the rolls when thus opened by the larger pieces, and so to escape the desired grinding, and the same may be said of coarser work, the relative proportion of sizes being the same.

A COARSE PIECE SEPARATING THE ROLLS

IN order to correct this defect as much as may be, and increase the efficiency in crushing the finer material that would otherwise pass the rolls, Mr. Pinder devised the sectional cushioned rolls in question. Their nature will be understood at once from the annexed sketch. The system, as applied to the Cornish, or ordinary rolls of that class consists of the division of one of the two rolls into several sections, and the introduction of a stiff rubber cushion for each section, fitting snugly into the bore of the hub, and closely around the shaft which passes through it. This cushion is made of the stiffest car-spring rubber. The sectional roll is driven by two steel arms, one on each side, keyed to the shaft, each arm passing through and pressing against the spokes of one-half of the sections. In the operation of this system it will be clear enough that when the larger and harder pieces of ore fall into the rolls, and the strain on the springs in the act of crushing causes the rolls to part, only that section in contact with such a piece will be parted until the necessary crushing pressure is reached, after which it will spring back



HOW THE SECTIONAL ROLL ACTS

into place, while all the other sections will continue to crush such finer material as may fall in contact with each, which might otherwise pass between solid rolls without crushing. Experiments with the system are said to have proved more than 30 per cent. increased results.

WITH the advantages of mechanical stokers for boiler furnaces known as well as they are to-day, it does seem a bit strange that the marine engineer has apparently not taken kindly to them; at any rate, they have not yet gained a footing aboard ship. It is worth noting, therefore, that what will probably be the first mechanical stoker installation in existence afloat is now being fitted to the boilers of one of the steamers of the Zenith Transit Line, on the Great American Lakes, plying between Duluth and Cleveland. The stokers will be those of the American Stoker Company, of New York,—of the underfeed type,—and their performance in their new field of operation ought to prove an interesting engineering experience. There is certainly no very good reason apparent why some device of this class that will work well on land should not work well at sea. The instalment in this particular case will comprise six stokers, three under each of the two boilers, and each of these groups is guaranteed to be capable of burning 1650 pounds of coal per hour under ordinary conditions, and 2100 pounds when forced.

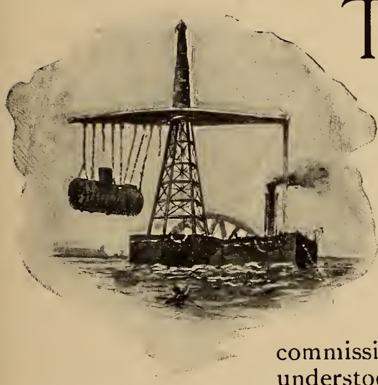
As a rule to which there are very few exceptions, no saving whatever is effected by making a boiler consume its own smoke. So says *The Engineer*, of London, in a recent discussion of fallacies concerning boilers, among which economy from smoke suppression is very properly classed. While, according to *The Engineer*, economy often results from the use of self-feeding furnaces, or other appliances, patented or unpatented, with which most engineers are quite familiar, the improvement is brought about by quite different agencies. Thus, for example, a mechanical stoker which works well will maintain steam pressure with more regularity than a man. The proper quantity of air can be admitted, and no more, and so on. It was shown many years ago by C. Wye Williams, who was the apostle of smoke-prevention, that the magnificent rolling billows of black smoke, poured forth from the funnel of a Holyhead mail steamer, owed their colour to a few ounces of finely divided carbon; that, in a word, a steamer's smoke trail closely resembles a comet's tail, in the insignificance of the quantity of tangible material which it contains. Sir W. Anderson showed far more recently that, so far from a smoky flame being a worse steam generator than a clear flame, it is far better. But the great practical fact is that boilers which are fitted to consume or prevent their own smoke, as a rule, are not such powerful smoke-producers as those which go through life smoking heavily and creating an atrocious nuisance, and the reason is not far to seek.

THE proper quantity of air required to burn a pound of coal is 12 lb. But this would suffice only if it were most carefully mixed with the products of combustion as well as supplied to the solid fuel. In practice nothing of the kind is possible. It is, indeed, hoped that something near it may be secured by the use of powdered coal suspended in an air current as fuel. But that result has not yet been obtained. With an admission of but 12 lb. of air per pound of coal, not only would a great deal of smoke be produced, but carbonic oxide as well. With well-managed fires we may get down to 18 lb. of air per pound of coal, but 24 lb. or 25 lb. is by no means an unusual quantity to admit if air is taken in over the fuel. The quantity often rises much higher. Now, every pound of air admitted to a furnace carries with it a number of heat units, represented by about one fourth of the number of degrees by which the air is hotter when leaving the boiler than it was when it entered the furnace. Thus,

if the external temperature was 60 deg. and the temperature in the last flue close to the boiler was 860 deg., then the air was 800 deg. hotter leaving the boiler than it was when it entered the furnace, and the loss would be about 200 units per pound of air. If we say that 1000 units represent a pound of steam, then each pound of air represents one-fifth of a pound of steam. The difference between a boiler furnace using 20 lb. of air and 25 lb. of air per pound of coal would then be a whole pound of water per pound of coal in favour of the former; or a boiler which, with 20 lb. of air per pound of coal, evaporated 8 lb. of water per pound of coal, would with 25 lb. of air evaporate only 7 lb. In the first case there might be smoke, in the second there might be none. The claims to economy put forward by many inventors are no doubt for the most part based on ignorance; and they are the more to be regretted because the mere prevention of smoke is in itself an end so desirable that steam users ought to be quite content with it, and not hope to attain the impossible.

GEORGE W. DICKIE

General Manager of the Union Iron Works, San Francisco



THE writer has been requested by the editor of CASSIER'S MAGAZINE to prepare a sketch of Mr. Dickie's professional life and services. The difficulties of such a commission will be understood by Mr. Dickie's friends, who well know his constant avoidance of the personal pronoun in his writings, addresses and conversation, and that such facts as should have place in a sketch like this, have to be strategically procured.

However, I have been favoured in this matter by several circumstances,—by the photographer, for one thing, who has produced an admirable portrait that comes near to furnishing a complete clue to the personality of the sitter; also by an acquaintance of nearly twenty years, covering copious discussions of comparative engineering practice in the United States and in Europe, and his part therein; and, most of all, by an intimate acquaintance with his estimable father, Mr. J. W. Dickie, who died in 1891 at eighty-six years of age.

Ship building seems to have been congenital in the Dickie family. For more than one hundred years the male members have been ship builders, in Scotland, down to 1869, the family home being in Arbroath, in Forfarshire, and Tay Port, in Fifeshire.

The removal of the family to the Pacific coast, in the United States, was due to the subject of this sketch, the middle one as to age of the three brothers, all of whom now reside at San Francisco. Mr. John Dickie, the eldest, is the ship-builder of the Fulton Engineering and Ship building Company; Mr. James Dickie is the ship-builder at the Union Iron Works; and of this latter company Mr. George W. Dickie is the manager and chief engineer.

These three brothers constituted the firm of Dickie Brothers, of San Francisco, ship-builders, of which Messrs. John and James Dickie were the active partners. The firm constructed many deep-water and coast vessels, among others the fleet of steam whaling vessels,

operated from San Francisco. In fact, no deep-water steam vessel has been built at San Francisco for twenty-five years past in which Mr. George W. Dickie has not had some part, either in the design or construction.

When Mr. Dickie came out of the Scotch schools, and had served a term in his father's shipyard, he made a break in the family's traditional calling by going off into what is called, in Great Britain, "engineering work;" first in textile machinery, then in locomotive work and other things, including hydraulics, gathering an invaluable experience in general construction without which his present responsible duties could not be discharged.

Seeing the approach of a revolution in shipping, the change from sail to steam and from wood to iron, and regarding himself still as a ship-builder, he left the Old World to explore the new one, and from a study of the North American Continent selected the Pacific coast as the most promising place for his energies.

This field was then unoccupied. It represented one side of a great continent, and that side toward the markets that should naturally absorb American products; but there was no encouragement; everything had to be built up, or "pioneered," as it is called in California.

After some prospecting of the Pacific coast, Mr. Dickie, while in San Francisco, saw an advertisement in one of the local papers inquiring for an engineer to erect gas works in that city, and promptly applied for the work, setting the time for beginning one week ahead. This week sufficed, with his knowledge of engineering work, to qualify him as a "gas engineer," and even an expert in the art. The works were successfully constructed in 1871, and have furnished a large part of the city supply at San Francisco down to within two years past, when want of room and changes in gas-making processes called for new works in the suburbs.

After completing the gas works, Mr. Dickie, on behalf of the same contractors, the Risdon Iron and Locomotive Works, undertook the design and construction of the hydraulic elevators in the great Palace Hotel in San Francisco, which, all things considered, represent one of the most successful examples of his early work in that city. These elevators, five in number, had all the functions and even the refinements of practice down to the present time. They were on the Armstrong system, with hydraulic rams controlled by balanced water-moved valves, differential as to power and water consumption, and in one case moved up to the limit of modern speed. This work remained without change for eighteen years, when some alterations were made to increase the speed of the carriages.

From this Mr. Dickie drifted into the ponderous work of the Comstock mines, the boldest practice the world has ever seen. Money and precedents were alike disregarded. Cumulative or stage compression of air on the Riedler system was among the developments, and water was raised against a pressure of 1000 pounds per inch. Perhaps the boldness of this work can be illustrated by saying that when the writer first met Mr. Dickie, about 1879, he was invited into the works to see a hydraulic pumping engine then being erected at a cost of $250,000 under a guarantee of successful performance. The organised machine included steam engines and high-pressure pumps to send water down a mine at a pressure of 1000 pounds per inch as a medium for conveying power to pumps situated at the lowest levels of one of the Comstock mines. This structure, when erected in the works, was 60 feet long, 23 feet wide, and 17 feet high,—one machine, integral in function and construction, a mass that weighed 400 tons. It is hard to convey an idea of the engineering practice of that period, or to imagine how resources in skill and implements were provided.

Mr. Joseph Moore, the manager and one of the owners of the Risdon Iron Works, was a man of great ability and possessed of a boldness that led to ventures in nearly all branches of construc-

tive engineering, which, with Mr. Dickie as chief engineer, were successfully carried out. Here Mr. Dickie had reached one of the highest salaried positions attainable in his profession, but the old instinct was at work, and when wooden ship-building, which had been established at San Francisco by John and James Dickie, failed to be profitable George Dickie began to cast about for the founding of a dockyard and iron ship-building works. When such a scheme was in part consummated, Mr. Dickie was induced to join the Union Iron Works Company, who were about to move their works to the Potrero, a suburb on San Francisco Bay, about one mile south of the centre of the city.

Mr. Dickie, with Mr. Irving M. Scott, the general manager, and a principal owner, entered upon this great work, which, considering its environment and the lack of local resources, the difficulties to be surmounted and the results attained, has scarcely a parallel in the whole world.

I will here remark upon a circumstance that has contributed in no small degree to the phenomenal development of this great enterprise, carried out without mistakes or changes worth mentioning. Mr. Scott, who, besides his administrative ability, is also an able engineer, represented "one side" of all propositions that arose, while Mr. Dickie would take a position *ex parte*, and a vigorous debate and contention each way would end in the choice of what was good and expedient. The writer, who has watched the development of the Union Iron Works from the beginning, can recall no instance wherein there has been any considerable change or substitution because of mistaken plans. The equipment, much of it, is novel and without precedent, and is, no doubt, in quality and efficiency equal to any of the best works in Europe.

Mr. Dickie is a man of wide attainments outside of his profession and gives a portion of his time to the study of economics, science, literature and the various social problems of our time, pursued in a quiet manner and as a result of natural habit. He has five sons, all heading for the ship-yard, some of them there indeed, and one in the old University of Glasgow, from where he writes two weekly letters to the family at San Mateo.

He takes much interest in the local affairs of the beautiful town of San Mateo, a residential place 25 miles from San Francisco, apparently more concerned in that than in his professional connection, which can be said to extend to all countries where ship-building is carried on. His method of analysis, habit of mind and mode of expression remind one of his famous countryman, Thomas Carlyle, but is devoid of the aggressive spirit that characterised the sage of Chelsea.

These methods and personal characteristics are derived in part from the training of the Scotch schools. These are usually in charge of a university man, who has in one corner of the room lads learning to spell and write, and in another corner students in the classics, or in calculus. It is a kind of pedagogy peculiar to Scotland, that treats an education as a whole and as the great and serious fact of one's life.

Mr. Dickie's writings and lectures embrace essays on commerce, the constructive arts, education, and the like, but are mainly directed to technical subjects. He recently visited Japan, and with unusual privileges and facilities examined carefully into the industrial, social and economical conditions of the Island Empire. His views are at a strange variance with those of some political agents sent out there to ascertain how soon American industries were to be brought into competition with that country. So important is this matter that the following extract from one of his addresses on this subject may be given here:—

"We may come now to a question that has agitated the manufacturers of this country and of Great Britain for some time, and has been used in this country as a political argument, that is, the question of Japanese competition in the various lines of manufacture that

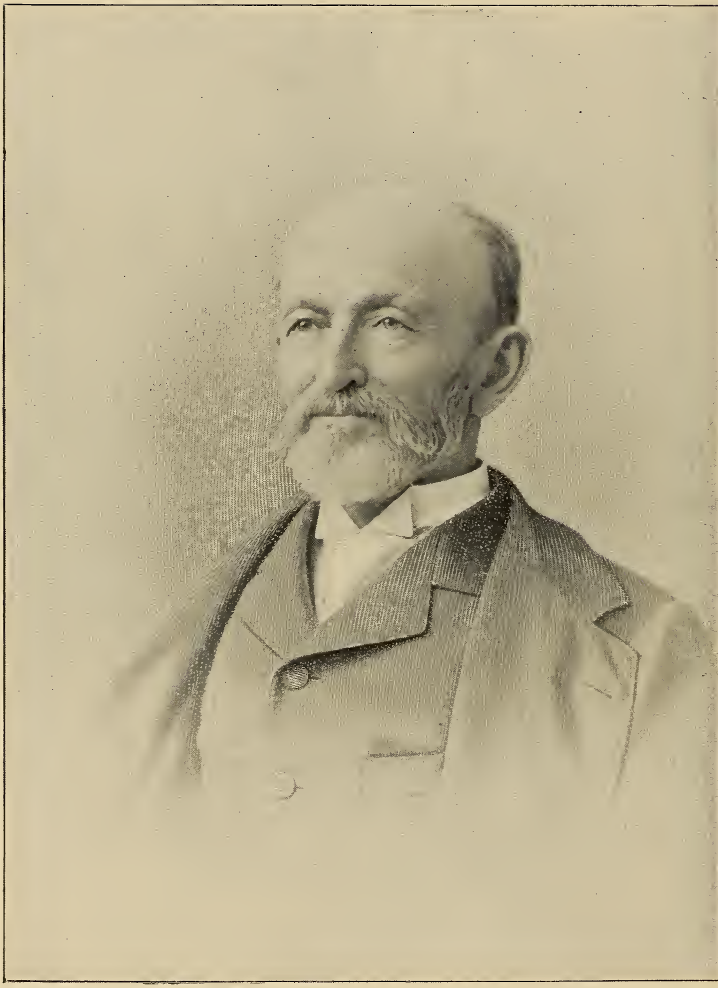
have, to some extent, been established in Japan.

"The Japanese are expert weavers, and when cotton mills began to appear in Osaka, there was no lack of skilled labour of the most efficient kind to do the work, and at a very much less cost than was possible either in Great Britain or America. The establishment of cotton mills has heretofore been a very profitable enterprise in Japan, and a large part of her own wants in this line are now supplied from her own mills. Yet Japan must come to this country for the raw material. She is also branching out in many other lines of manufacture, and nothing that this country or Great Britain can do will prevent them from doing for themselves what they can do cheaper than others can do for them.

"What did we force our civilisation upon them for but this very thing, and why should we complain at the result? But we need not be alarmed. Japan is not to be such a powerful factor in the industries of the world as recent writers on the subject would make us believe. As she develops in wealth, her people will develop wants that they never knew of before. "We are told that these people can produce cotton cloth for the world. When they are able to send us the material for our white shirts and dainty calico dresses, will they be satisfied, think you, with only a loin cloth for themselves? The leaven is working now in the social mass of the Japanese people that will raise all the questions for her to solve that have confronted other people, and her people will demand what others have, and that will make work enough for her mills, with, say, forty millions of her forty-four millions practically naked.

"We need not fear the competition of a few cotton mills at Osaka. Great Britain has 45,270,000 spindles; India has 3,649,736 spindles, and had not any when Japan began to build cotton mills. Japan now has only 984,557 spindles. We hear very little of India supplying the markets of the world with cotton; yet she can produce four yards to one of Japan. The proposition is absurd and not worthy of serious consideration."

JOHN RICHARDS.



PHOTOGRAPH BY THE F. GUTEKUNST CO., PHILADELPHIA.

Chas. H. Cramp

(See Page 323)

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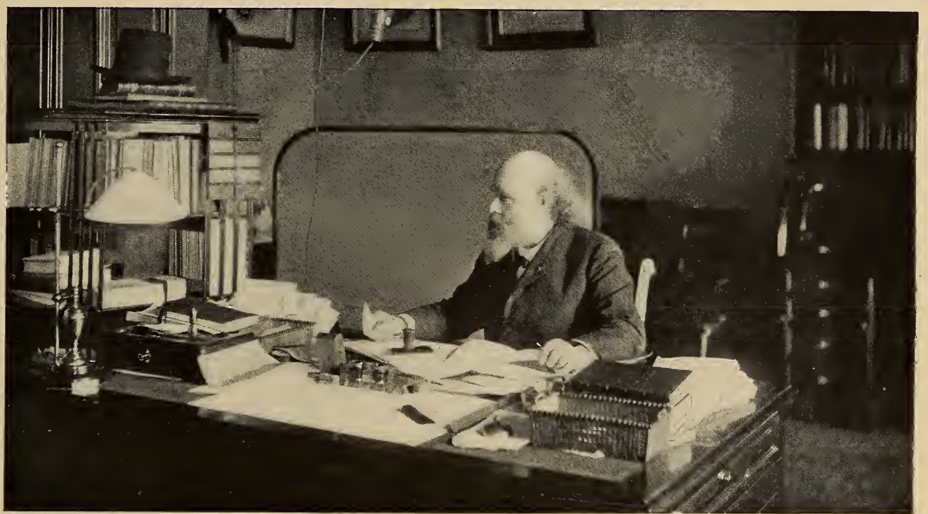


COMMODORE GEORGE WALLACE MELVILLE

FROM A RECENT PHOTOGRAPH

THE OUTLOOK IN MARINE ENGINEERING

By Commodore George W. Melville, Engineer-in-Chief of the United States Navy

PART I.—SPEED OF SHIPS, AND ECONOMY IN STEAM USING AND STEAM MAKING

WHILE real progress in the arts must depend mainly on original research, which gives us definite facts to serve as points of departure in formulating theories, or framing explanations, benefit may still be derived from an examination of existing conditions with a view to the formation of definite opinions as to the lines of future progress. While, therefore, not originators, we may at least contribute to improvement by taking advantage of the best that has been done, and making our own work so far perfect that it will stimulate men of original genius to further effort.

The recognition of this fact has led to retrospective articles and addresses before learned societies from time to time, many of which have had great value,

and the writer believes that the present is an appropriate time to note some important changes which have occurred in marine engineering, and to consider the tendencies of design as they may be deduced from existing practice, both as respects war vessels and the merchant marine.

Speed of Ships

Speed of ship is a vital factor in marine engineering, for the greatest improvements in design and manufacture have resulted from the demands for higher speeds.

Twenty-five years ago the highest sea-speeds for merchant steamers were less than 16 knots, and for war vessels were even less, except in such notable cases as the cruiser *Wampanoag*, of the United States Navy. In the merchant service the increase of speed has been gradual since the advent of the *Arizona* with 17 knots, every few years at least bringing out one or more faster "greyhounds," until we have the *Kaiser Wilhelm der Grosse*, with a record of 564 knots for a day's steaming and an average for that day of 22.83 knots.

After the wonderful record of the *Wampanoag*, in 1868, when she averaged over 17 knots for six hours, the speeds of war vessels fell off for a time, and did not again become noteworthy until the performance of the *Esmeralda*, built by the Armstrongs in 1883. That vessel made over 18 knots, and inaugurated the present era of high speeds, giving us the triple-screw flyers, *Columbia* and *Minneapolis*, of the United States Navy, each of which held the record for a time at 22.8 and 23.07 knots, until another Armstrong vessel, the *Buenos Aires*, of the Argentine Navy, captured it with a speed of 23.2 knots.

The record for torpedo-boats is still more remarkable. Beginning more than twenty years ago, with lengths of less than 100 feet and speeds of 19 knots, torpedo-boats have grown into such vessels as the *Forban*, of 31 knots, and the phenomenal (phenomenal because of the small size of vessel,—only 44.5 tons) *Turbinia*, of 31 knots; and with them have come the destroyers, with speeds of 32 knots, and, if we can believe the reports, one of Schichau's boats, which is said to have recently made 35 knots.

The same increase of speed is clearly evident for battleships and armoured cruisers, where we have now reached the point of 23 knots for the *Jeanne d'Arc* and the new *Powerfuls*, and 21 knots for the projected Italian battleships.

If we can argue fairly from these records, it must be very evident that the tendency is toward still higher speeds, and such is undoubtedly the case. The tentative plan of the Board of Construction of the United States Navy Department for the new ships which Congress has been asked to authorise at the coming session shows a very distinct advance in speeds for all the larger ships of every class, and a study of the building programmes of other navies shows the same thing. Speed is so absolutely vital to success in naval warfare that as long as the engineer will respond to the demands on him for greater power without corresponding increase of weight, these demands will be made.

It would be futile to attempt a prediction as to the limit of speed. Thirty years ago, the speeds which are now common would have been deemed incredible, and, while it does not seem possible that there could be such an increase in the future, no one can fix the limit. The increase in speeds has been made possible by the improved economy of the machinery and the reduction of weight per unit of power, the former being an important element in the latter.

Economy in the Use of Steam

For a long time, the improved economy was almost entirely in the steam using, the boiler efficiency remaining almost constant. The first steps of improvement were the gradual increase of steam pressures to about 60 pounds, and the general use of the steam jacket, combined with surface condensation,

the steam doing its work, however, in one stage of expansion. The cost of a horse-power had been reduced from something over 5 pounds of coal to something less than 3 pounds.

Then came the period of the compound engine, running from the '60's down to about 1881, during which steam pressures rose to about 120 pounds, and the cost of a horse-power fell, in specially economical cases, to about 2 pounds of coal, although the average cost was probably about 2½ pounds. During this period the reasons for the losses in the steam-engine were gradually worked out, in which work Chief Engineer B. F. Isherwood, U. S. N., took so important a part.

It had been believed by many that, from an economical standpoint, expansion could not be carried too far, and Isherwood was the first to prove experimentally that this is entirely wrong, the truth being that after passing a certain degree of expansion, any greater degree causes an actual loss. The extended practice with the fine compound engines toward the end of this period showed that this principle had become thoroughly understood, for they worked at 120 pounds with fewer expansions than some designers in the early '60's had attempted in a single-cylinder with 30 pounds.

When improved materials and workmanship, combined with improved design, had made higher pressures possible, the triple-expansion engine was introduced, the first successful example being the *Aberdeen*, designed by Dr. A. C. Kirk, and built in 1881. This was the real beginning of triple-expansion engines, and four-stage expansion soon followed. As yet, however, the great majority of designers have not considered the possibilities of three-stage expansion exhausted, and although the Cramps have used quadruple-expansion engines at 210 pounds in the *St. Louis* and *St. Paul*, with great success, and the *Kaiser Friedrich* also uses this type of engine at 220 pounds, the *Kaiser Wilhelm der Grosse* has triple-expansion engines using steam at 185 pounds. The same thing is true in naval practice. There are quadruple-expansion engines in the *Cushing* and *Nashville*, of the United States Navy, using 250 pounds pressure, but the new United States destroyers, which will carry that pressure at the engines and 300 pounds at the boilers, are to have four-cylinder triple-expansion engines. Sir John Durston, Engineer-in-Chief of the British Navy, who has been the leader in very high pressures for large engines, has stuck to the four-cylinder, three-stage type, with a pressure of 250 pounds at the engines and 300 pounds at the boilers.

During this period the cost of a horse-power hour has been reduced to at least 1.5 pounds of good coal for periods exceeding 24 hours, and there are trial-trip records as low as 1.25. In one case, that of the British steamer *Inchmona*, it is reported that the consumption was as low as 1.07 pounds of coal, and that not of the very best quality. In these cases, boilers of great economy, feed-heaters and other factors contribute to this great reduction. The *Inchmona* has a five-cylinder, four-stage engine, carrying 255 pounds pressure, the design of the late Mr. Thomas Mudd. We do know, however, on the very highest authority, that, on another of Mr. Mudd's ships, the *Iona*, where the feed-water was carefully measured, the steam consumed per I. H. P. was 15.5 pounds from and at 212° F. There is no record of the steam consumption for the cases of greater economy, but as in this case the coal per I. H. P. was 1.46 pounds, it is fair to assume that for them the steam consumption was less than 15 pounds per I. H. P. hour, and, on a basis of the same boiler efficiency, the *Inchmona* would use 11.35 pounds of steam per I. H. P. hour.

Under the more favourable conditions obtaining on shore, results approaching this figure have been obtained with compound engines carrying 125 pounds, but with superheated steam and reheaters in the receivers.

What the next step in advance will be is exceedingly difficult to predict. The former difficulty of securing higher pressures on account of the boiler has

disappeared with the success of the water-tube boiler, and any reasonable pressure can now be obtained if desired. There are, however, as is well known, a great many practical difficulties in the use of steam of very high pressures. Those now becoming common have, on account of the high temperature, driven out copper steam-pipes, which are replaced by those of steel. The high temperatures also make internal lubrication difficult, and even if we consider that there need be no internal lubrication in vertical engines, there remain the excessive expansion and distortion of complicated cylinders, and other evils.

The use of reheaters in the receivers, to prevent and remedy cylinder condensation, has been recommended by some very able engineers, and their success in land engines makes this seem one method of increasing economy afloat. They have already been used on a small marine engine, and are reported as of great practical benefit in keeping the cylinders clear of water, leaving the question of economy to be determined,—this not being an important item in the yacht where this particular engine is installed.

The possibility of some practicable change in valve-gear which would enable the clearances to be greatly reduced has been repeatedly discussed, and if this could be accomplished successfully there would certainly be a gain in economy. Thus far, however, this line does not look promising. For fast-running engines, which must remain the rule in marine practice, nothing has yet been brought forward which is, on the whole, so satisfactory as the link motion, and this involves large clearances.

Superheating is, of course, always in mind, and it is again being tried with some success on shore. Its use on shipboard was never very satisfactory, even in the days of lower pressures, and the objections to higher pressures on the ground of the accompanying extreme temperatures apply even more strongly where these temperatures are in dry, rather than moist, steam. Until superheating is demonstrated by the shore experiments to be an unqualified success, it does not seem likely to be tried again in marine work.

The effort to make some of the surfaces with which the steam comes in contact in its passage through the engine non-conducting, or nearly so, which was inaugurated by Dr. Robert H. Thurston, would, if successful, be a great step in advance. Even if the method he used should fail, it suggests a promising field, and some genius may yet discover a solution of the problem.

We may thus anticipate the adoption of reheaters in the near future, and a gradual increase of pressures with the use of four-stage engines. As experience is gained, moderate superheating, enough at least to give dry steam in the first cylinder, may be adopted.

Economy in Steam Making

At the time of the American Civil War the almost universal practice for marine boilers was to make them of what is known as the "box type," or what has more recently been referred to in an English work as the "tank boiler." This was really a cubical box whose sides were quite thin, and which depended for its strength entirely upon braces. Under natural draught,—which was then the prevailing condition,—these boilers gave a fair economy, the average being about 60 to 65 per cent. When higher pressures became common, with the advent of the compound engine, this type of boiler was no longer possible, and we then had what is familiarly called the Scotch, or cylindrical, boiler.

In the early days, attempts were made to economise in the room taken up by this type of boiler by making it elliptical; but this, of course, necessitated heavy braces, and as the pressures rose, this also became impossible, and the standard type became, and has remained for many years, the cylindrical boiler. While the general design of the boiler has been practically unchanged, there have been variations in the number of furnaces and in the arrangement of the combustion chambers, depending

TABLE I.—EXPERIMENTS ON SHORE WITH A BABCOCK & WILCOX BOILER, INTENDED FOR U. S. S. "ATLANTA," WITH AND WITHOUT HEATED DRAUGHT.

Heating surface, 1950 sq. ft.; Grate surface, 54.7 sq. ft.; ratio 35 to 1. Duration of each trial, 6 hours.

Kind of Draught Used.		Heated.	Heated.	Heated.	Cold.	Cold.
Boiler pressure		200	200	200	184	200
Feed temperature, degrees Fahr.		110	110	110	110	110
Factor of evaporation		1.162	1.162	1.162	1.162	1.162
Average Air Pressures in Inches of Water.	Chimney	—0.48	—0.40	—0.27	—0.33	—0.42
	Flue	—0.22	—0.26	—0.26	—0.09	+0.07
	Furnace	+0.15	—0.04	—0.24	+0.08	+0.43
	Fire room	+1.05	+0 70	0.00	+0.48	+1.03
	Ash-pit	+0.48	+0.30	—0.12	+0.48	+1.03
Temperatures, degrees Fahr.	Air in fire-room (entering air heater)	91	83	161	99	91
	" ash-pit (leaving air heater)	290	273	311	99	91
		Lead Melted	Lead Melted	Bismuth Melted	Zinc Melted	Aluminum Melted
	Gases in chimney by pyrometer	657	545	488	----	----
Moisture in steam, per cent		00.43	00.65	00.58	00.49	00.57
Dry coal per hour, pounds		1558	1199.5	679	1368.7	1813.3
" " per sq. ft. of grate, pounds		28.48	21.92	12.41	25.02	33.15
Refuse in coal, per cent		10.3	9.8	10.8	9.7	8 23
Water Evaporated.	Per pound of dry coal, actual conditions	8.22	8.56	9.4	8.02	7.62
	" " " f. and a. 212° Fahr	9.55	9.94	10.93	9.30	8.54
	Per pound of combustible from and at 212° Fahr	10.65	11.02	12.25	10.30	9.31
	Per sq. ft. of heating surface per hr. f. and a. 212° Fahr.	7.63	6.12	3.81	6.53	8.24
	" " grate " " " " "	271 9	218.1	135.7	232.7	294.6

partly on the desire to save weight and complication, and partly also on the ideas of individual designers.

In the early days, both for the box boiler and for the early cylindrical boilers, the ratio of heating to grate surface was about 25 or 26 to 1. This was found by experience to give satisfactory results for the amount of coal which could be burned with natural draught. When forced draught was introduced, it was, of course, apparent that the ratio of heating to grate surface must be increased to properly abstract the heat from the greater amount of coal burned, and the ratio became 30 to 35 to 1 for the boilers used in war vessels and in those merchant vessels where weight was more important than economy. In other merchant vessels, however, where the power was small relative to the size of the ship, and economy was an extremely important feature, this ratio became as high in some cases as 75 to 1.

For a long time the economy of steam production remained practically constant, and, if anything, fell off a little when the change was first made to cylindrical boilers. Attempts were made, by the use of superheaters, and of feed-water heaters in the uptakes, to reduce the temperature of the escaping gases as low as possible, but the rapid deterioration of these devices led to their falling into disfavour, and they have been practically abandoned. More recently, however, the feed-water heater in the uptake has again come into favour with water-tube boilers, and in those cases where the heater is designed as an integral part of the boiler, it can be cared for as well as the main boiler, and hence should give satisfaction. As is well known, this is the practice with the latest types of Belleville boilers as introduced into the British and French navies.

Mr. James Howden, the inventor of the Howden system of forced draught, has done a great deal, not only for the production of greater power from the same weight of boiler, but for increasing the economy with which the steam is produced. His method is to heat the air before admission to the ash-pits by means of special air heaters, located in the uptakes. The writer is not aware of any record of evaporative tests which have been made of boilers on this system, so that the performance of the boiler could be determined apart from that of the engine, but combined tests have shown remarkably economical results, having been reported as low as 1.25 pounds of coal per horse-power with triple-expansion engines working

at 160 pounds. There can be no doubt of the decided increase of economy by this system, and it is now used on nearly all the large trans-Atlantic steamers, to a great extent on the vessels on the Great American Lakes, and it is being actively pushed on the Pacific coast of the United States.

Contemporaneous with the growth of the cylindrical boiler has been that of the water-tube boiler, whose advantages in the way of reduced weight, facility for raising steam, security against disastrous explosion, and ability to stand rough treatment from a thermal point of view, commend it highly. In most of these boilers, unless fitted with special appliances, there is a decided reduction of economy under forced draught, owing to the facility with which the heated gases can escape to the uptake. Several of the small-tube boilers, however,—notably the Thornycroft, Normand, and Mosher,—have the tubes so disposed that the gases are compelled to take a circuitous route and pass over the entire heating surface under all conditions.

TABLE II.—THORNYCROFT BOILER OF U. S. S. "CUSHING" ("SPEEDY" TYPE).

Air pressure in inches of water	*0.00	0.5	3.0	4.0
Steam pressure (per gauge) pounds	250	250	250	250
Coal per hr. sq. ft. of G. S.	7.58	24.12	40.23	66.32
Actual evapn. from and at 212° Fahr. per pound of coal	11.90	9.72	8.84	6.51
Actual evapn. from and at 212° per sq. ft. of heating surface	1.40	3.63	5.51	6.70
I. H. P. per 100 sq. ft. of heating surface on basis of 17 lbs. of steam per I. H. P. f. and a. 212° Fahr.	8.25	21.40	32.30	39.45
I. H. P. per ton of boiler and water on same basis	18.35	47.60	72.10	87.80

*Blowers discharging into open fire room.

Naturally there is some reduction of economy under high forcing, but the general average is higher than that of other boilers where there is either no special provision, or where the only means of causing circulation of the gases is by baffles. Heated ash-pit draught has not hitherto been applied to boilers of this type in regular service, although there is no reason why it should not be, and the benefits are very evident.

It was remarked above that, so far as the writer knows, no reports of evaporative tests of boilers fitted with Howden draught have been published. Table I., however, showing tests of one of the Babcock and Wilcox boilers for the U.S. cruiser *Atlanta*, gives data showing the benefit to be derived from heating the air. In explanation of the air pressures in the table, it should be said that the boiler was inclosed in a structure into which the air was forced by a blower, thus insuring ample ventilation and a moderate temperature. From this closed fire-room the air passed through the air heater, or regenerator, and thence by a duct to the closed ash-pits. When the air was not heated, the opening to the regenerator was closed and the ash-pits were opened. An examination of the table shows very clearly both the increased evaporation per pound of coal and the reduced temperature in the chimney when the regenerator is in use.

That a large amount of heating surface is the important factor in the economy of steam production is shown by the case of the *Iona*, where the evaporation from and at 212° F. was 10.63 pounds with coal whose calorific value was 14,830 thermal units, and the coal burned per square foot of grate was 22.4 pounds. The efficiency of the boiler in this case was 69.2 per cent. Table II., showing the rate of variation of economy of steam production, with the increase in rate of combustion for the Thornycroft boilers of the United States torpedo-boat *Cushing*, is also very interesting.

As we have already seen, nearly everything possible has been done to contribute to economy of steam using, and much attention has, in recent years, been directed to secure the greatest economy in steam production. Features which will contribute to further economy in this direction are well understood, and, in fact, most of them have been practiced to some extent. Some of the best examples have secured an economy very close to the maximum possible, as there are certain losses which are inevitable, such as the necessary stack

temperature for natural draught, radiation, unburned coal, and others.

For use on shipboard some of the features which would contribute to economy are inadmissible under many conditions. This was shown very clearly in the report of the United States Bureau of Steam Engineering for 1891, where a comparison was made between the weights of the boilers of the United States cruiser *Baltimore* and the British steamer *Iona*. Both vessels were of about the same displacement, but the adopted. With water-tube boilers, which are so much lighter, and which can readily have much greater heating surface on the same weight, this does not apply.

Attention has, of late, been specially called to another feature in economical steam making, namely, that of feed-water heating by live steam, where the temperature of the feed is made, as nearly as possible, to correspond to that due to the pressure of steam carried. The simple economy due to an increase

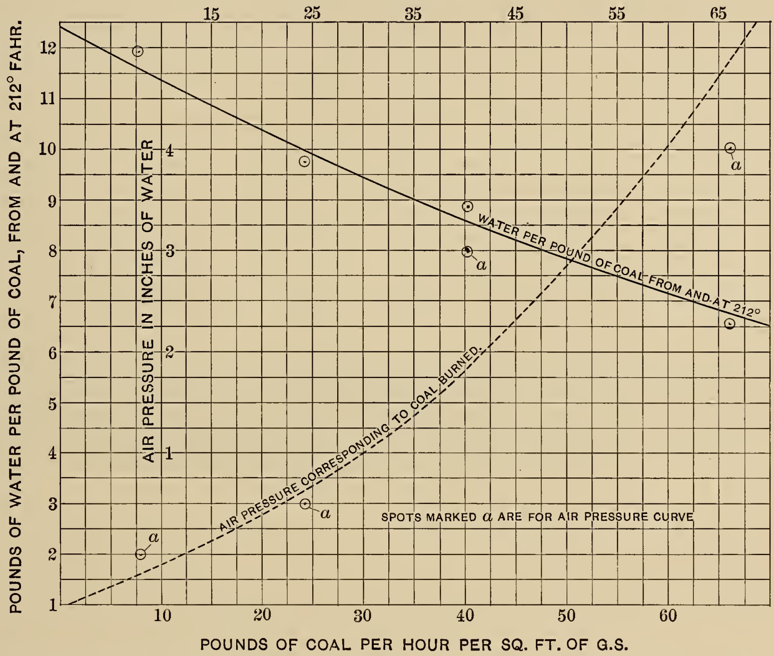


CHART OF TEST RESULTS WITH THORNYCROFT BOILER OF THE U. S. TORPEDO BOAT "CUSHING"

Baltimore had to furnish steam for 10,000 horse-power, while the *Iona* demanded only 700 I. H. P. It was shown in the report that, had the boilers of the *Baltimore* been designed for economy on the same ratio as those of the *Iona*, they alone would have weighed 1743 tons, while the entire machinery of the *Baltimore*, as built, weighed only 995 tons. It is very evident, therefore, why, in war vessels, and in very fast passenger steamers, other methods of securing economy than large heating surface must be of feed temperature was, of course, always understood; but when feed-water heaters using live steam were introduced some years ago, it was a source of surprise to most engineers that there should be a material increase in the economy of evaporation. It did not seem, at first, that there could be any special economy from this, as the steam which was used to heat the feed-water had previously been generated in the boiler in the ordinary way.

This subject has, however, been discussed pretty thoroughly of late in the

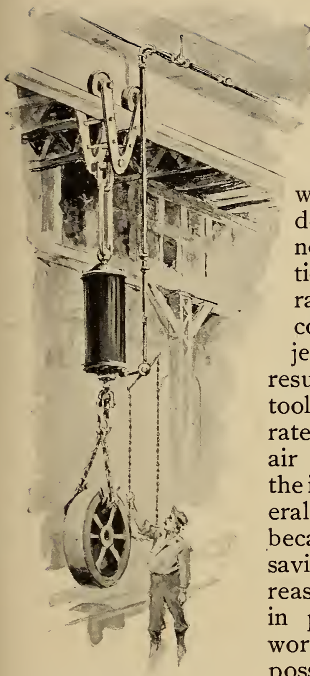
engineering press, and not long since Mr. McFarlane Gray called special attention to it at a meeting of the Institution of Naval Architects, where he pointed out that the essential feature was to make the function of the heating surfaces of the boiler merely the transmission of the latent heat necessary to turn the heated water into steam. This would seem almost to be a contradiction of the law of the transmission of heat, but it appears that the increased efficiency of the heating surface is due to the more rapid motion of the heated water over the surface.

It would seem, therefore, that the tendency in boiler practice is toward a greater ratio of heating to grate surface, forced draught, air heaters, and feed-water heaters for putting the water into the boilers as near the temperature of the steam as possible.

Part II. of this article, which will appear in the March number of this magazine, will deal with the design of marine machinery, marine auxiliaries, the steam turbine for marine use, liquid fuel, and the propeller, all discussed in Commodore Melville's characteristic, admirable manner.

PNEUMATIC SHOP APPLIANCES

By Whitfield Price Pressinger



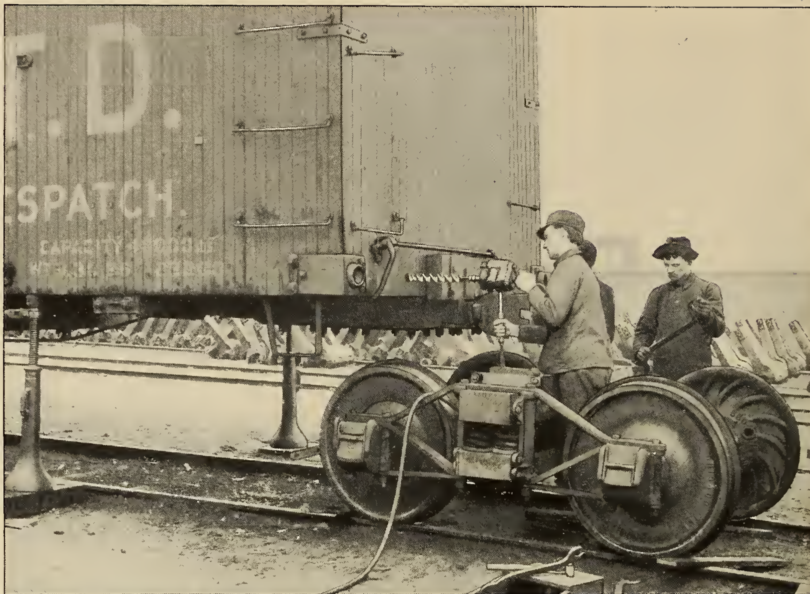
A COMPRESSED AIR HOIST

PNEUMATIC shop tools have been much discussed of late, and it is not the purpose of the writer, therefore, to describe any startling novelties in pneumatic equipment, but rather to present, as concisely as the subject may permit, a resumé of the various tools and devices operated by compressed air that have received the indorsement of general adoption, either because of their labour-saving properties or by reason of their efficiency in producing better workmanship than is possible by hand.

The pneumatic shop tool possessing the widest range of usefulness, and which, for this reason, has been the most generally utilised, is the well-known pneumatic hand hammer, consisting of a cylinder having at one end a threaded orifice to receive the air supply pipe connection, and at its other end an opening to receive a bit or chisel suited to the kind of work to be done. Operating within this cylinder is a piston, which also acts as the hammer, varying in size to suit light or heavy duty, and with a stroke ranging from half an inch to five inches. In some classes of work the short stroke is desirable, while in others the long stroke is indispensable. This combined piston and hammer is caused to reciprocate within the cylinder at a very high rate of speed,—estimated in some instances at 7500 strokes per minute,—by the alternate admission of air to the upper and lower sides of the piston.

In some types of these tools, a valve is employed for controlling the admission of air to the opposite sides of the piston, while in others the piston acts as its own valve. The pneumatic hammer has proven particularly efficient in calking boilers, iron and steel ships, and similar duty, chipping either wrought or cast metals, removing the scales from castings and armour plate, riveting in places inaccessible for hand work, and in cutting, carving and dressing metal, granite and other stones. In these different fields of usefulness the pneumatic hammer will save the labour of from two to ten men.

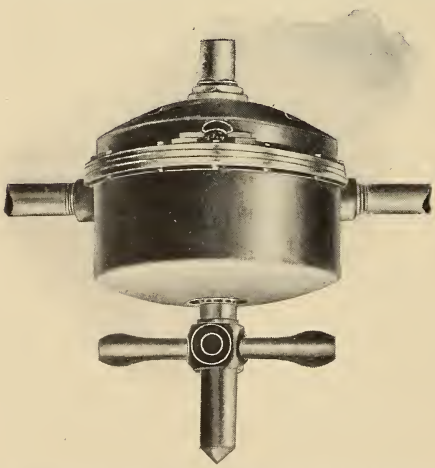
The pneumatic drill, which is, in reality, a portable motor, is adapted to a varied number of uses, and it has found wide favour in shop practice. These drills are of two types, with rotary and with reciprocating piston, each having their quota of advocates. In the boiler shop they are particularly useful for reaming and tapping stay-bolts, while in the machine shop they are employed for drilling at remote points and where the work is too heavy to be conveniently moved to the boring mill. They are utilised also to advantage in operating cylinder-boring bars, and in facing valve seats. In ship and bridge work they are extensively used for all drilling and reaming. This same drill, with but slight changes in its construction, also serves for boring holes in wood, in car work, agricultural work, and ship and bridge work. The pneumatic breast drill, as its name implies, is a small reproduction of the larger drill, and is of exceptional utility for a number of purposes where small holes are required. This drill is light



A COMPRESSED AIR BORING MACHINE, MADE BY THE STANDARD PNEUMATIC TOOL CO., CHICAGO

and easy to handle, weighing not more than eight or nine pounds.

Pneumatic hoists of different styles are extensively used in machine and



A PNEUMATIC TAPPING, REAMING AND DRILLING MACHINE, MADE BY MESSRS. TAITE, HOWARD & CO., LTD., LONDON

boiler shops, foundries, shipyards, bridge works, slaughter houses, breweries, factories in every branch of trade, in all places, in fact, where it is necessary to raise heavy loads frequently and expeditiously. The type of hoist in most general use, and the one possessing the widest range of adaptability, is the ordinary direct-acting straight-lift hoist. This is simply a cylinder suspended from the top end, and fitted with a piston and piston rod, the latter having a hook at its lower end for receiving the weight. In the smaller sizes of these hoists, the cylinder usually consists of ordinary brass tubing with cast heads held in place by tie rods passing through the heads and secured by nuts. In the larger hoists, the cylinder is a casting, bored out to the proper diameter.

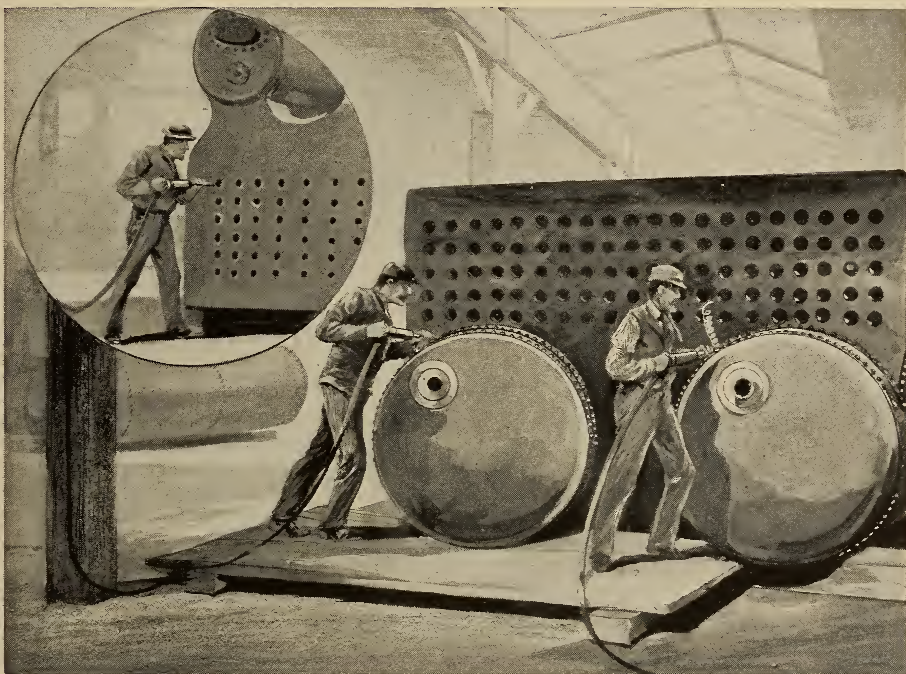
When the nature of the service permits, the hoists are suspended in a fixed and permanent location, but their greatest field of usefulness is realised by suspending them from a trolley running on an overhead rail. When so arranged, the air supply hose is sufficiently long to permit the hoist to be moved the entire length of the overhead rail. The hose is wound upon a drum and passes over idlers arranged alongside of the rail, a spring being utilised for rewind-

ing the hose upon the drum as the hoist returns.

Another method is to disconnect the hose from the hoist when necessary, by means of a convenient coupling, the ecsape of air being prevented through the automatic closing of the valve by the air pressure. With this arrangement, the range of travel of the hoist with its load is unrestricted. The hoist requires no labour other than the manipulation of a three-way valve, and the load may be held at any point, at will. The speed of lifting is variable, being entirely under the control of the operator, and the workman does not have to wait for slowly moving mechanism, as in chain hoists.

Horizontal cylinder hoists may be used in cases where head room is lacking, and these are constructed in a variety of forms; but wherever the conditions will permit, whether upon cranes or otherwise, the vertical direct-acting type is preferable, as it is more easily operated, is higher in efficiency, and lifts more evenly and smoothly than the other type.

When it is impossible to utilise either the vertical or horizontal hoists, the air motor hoist may be used to advantage. In this device the common differential chain hoist is provided with an air motor similar to that used in the rotary drill previously referred to, fitted between the side plates which form the frame of the hoist. A pinion is placed upon the air motor shaft and meshes with the gear of the hoist proper. Many advantages are claimed for this combination, among them the small amount of head room which it occupies, and its unlimited length of lift, a range of 10 feet being ordinarily provided for. As in the chain hoist, it will hold its load at any desired point without strain upon the motor.

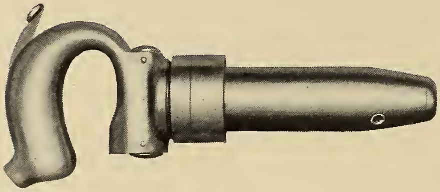


PNEUMATIC TOOLS FOR BOILER WORK, MADE BY THE CHICAGO PNEUMATIC TOOL CO., CHICAGO

Air hoists of the several types mentioned are used in machine shops over lathes, planers, and boring mills; in fact, at all points where the load is too heavy for one man to lift. In boiler shops it

is employed for handling the sheets, boiler fronts and the finished product. The foundry utilises the hoist for handling materials, flasks, ladles and the completed casting.

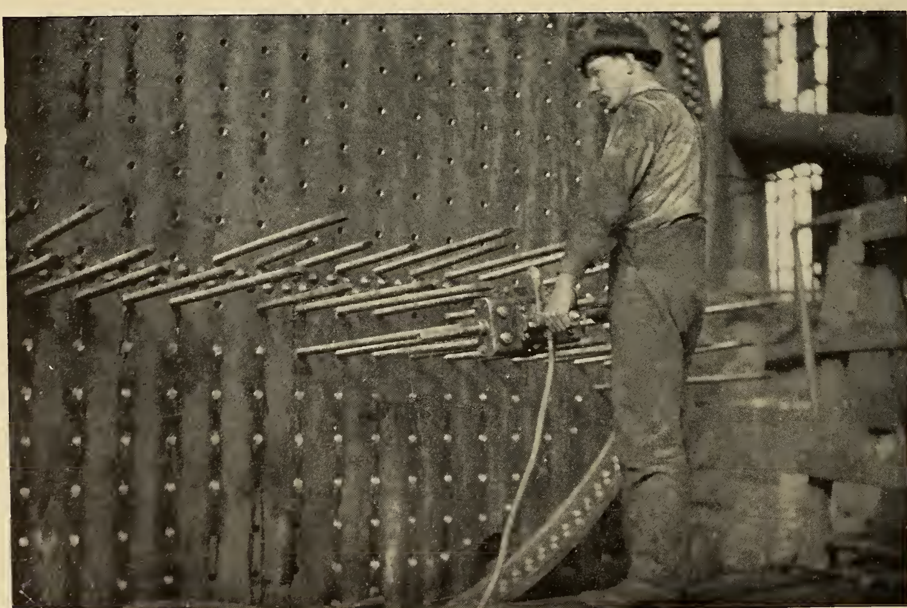
In car shops and in other places, a compressed air appliance, the utility of which is analogous to that of the hoist,



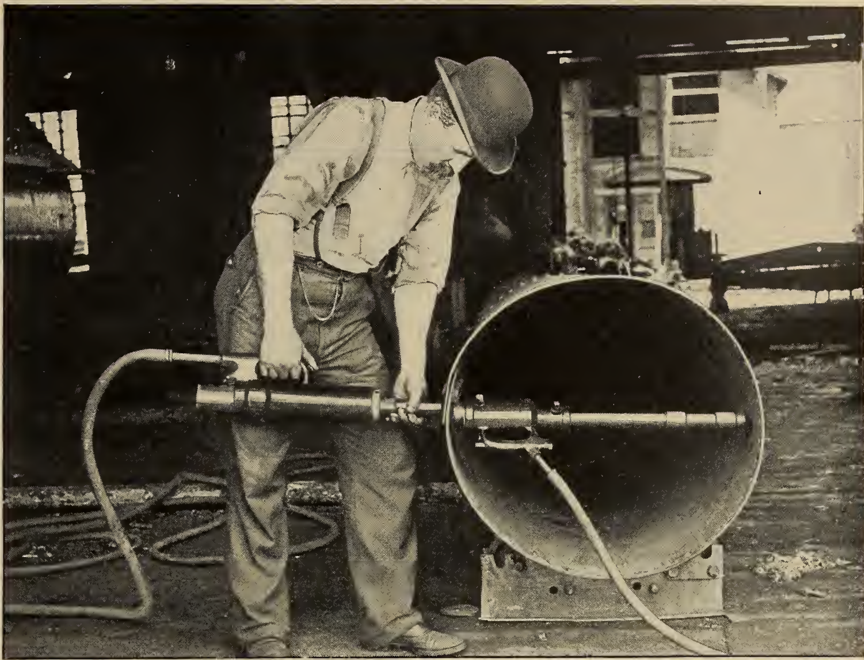
A PNEUMATIC HAMMER

is the now almost indispensable pneumatic jack. This tool is made in a number of different sizes, and is as important in its own sphere as is the hoist in its various applications. It consists of an iron cylinder with two lugs by which it is carried from place to place on a small truck. A three-way valve admits air which raises the piston in the cylinder; by turning this valve the air is shut off and the exhaust opened, a spring forcing the piston down when the jack is empty. The air inlet is fitted with a check valve, making it impossible for the load to drop too suddenly should the air hose break and the pressure be released. With the old form of hand jack, it took two men ten minutes to do the work which one man can now do in three minutes.

In riveting operations compressed air has been recognised as possessing superior merits over steam or hydraulic power, as it dispenses with the necessity of expensive accumulators, hydraulic piping or discharge pipes. There is no danger from freezing, knocking out cylinder heads, or otherwise damaging the riveter, and it can be used as well out of doors as under shelter. Pneumatic riveters are made in a number of different forms. There is, for example, the stationary or stack riveter, which is designed especially for heavy riveting, and where the work is to be brought to the machine. Riveters of this class are made to close up the rivet by a single squeeze, as in those of the hydraulic



SCREWING IN 1¼-INCH DIAMETER STAY BOLTS IN A LARGE MARINE BOILER. THE HOLES WERE TAPPED BY THE SAME MACHINE. MADE BY THE C. H. HAESELER CO., PHILADELPHIA



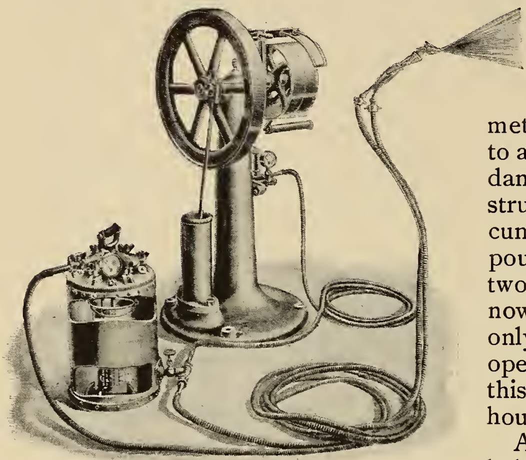
PNEUMATIC DUPLEX RIVETER AND HOLDER-ON, MADE BY THE Q. & C. COMPANY, CHICAGO, ILL.

type, and are also designed to drive the rivet by the percussive action of the hammer. In one form of riveter, the squeezing operation is accomplished by the action of compressed air upon a body of oil contained in a suitable cylinder and operating on a piston for actuating the die.

A form of pneumatic riveter recently introduced is of the yoke type, the yokes being of light trussed angle construction, and having in one arm a pneumatic hammer of the style used for calking and chipping; the other arm of the yoke carries a pneumatic holder-on. These yokes are readily detachable, and special yokes for special work may be quickly substituted. A riveter constructed after the pattern described, and which has a capacity up to 7/8-inch rivets, weighs but a little more than 80 pounds, and a riveter capable of driving up to 1 1/4-inch rivets does not exceed 175 pounds in weight. The rivets are driven as fast as they can be placed in position. When long reaches are to be made, the yoke may have a depth of six feet or over; in this case, the yoke

A PNEUMATIC CHIPPING TOOL, MADE BY THE STANDARD PNEUMATIC TOOL CO.

preferably consists of a heavy piece of iron piping, bent into *U*-shape and hung in an iron bail. This latter form of riv-



A COMPRESSED-AIR PAINTING MACHINE, MADE BY MESSRS. A. C. WELLS & CO., LONDON

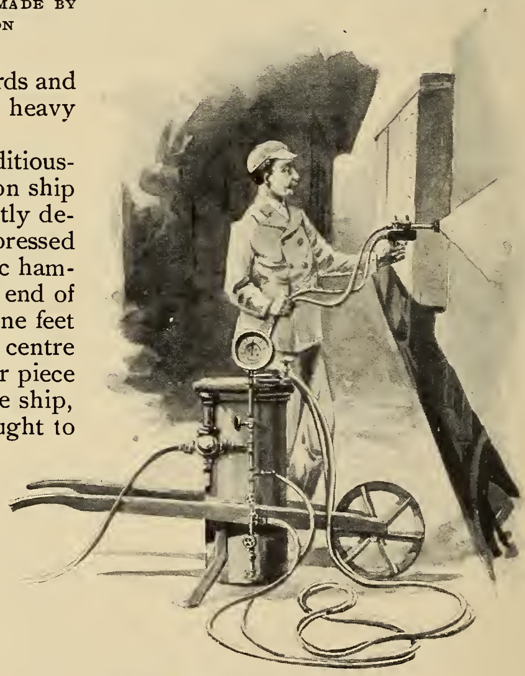
eter is used extensively in shipyards and tank shops for erecting in place heavy stacks and water towers.

The difficult operation of expeditiously riveting the bottom of an iron ship seems to be overcome by a recently devised riveter, operated by compressed air. This consists of a pneumatic hammer mounted in gimbals on the end of a piece of pipe about eight or nine feet long, which pipe is hung by its centre to a trolley running upon another piece of pipe bolted to the bottom of the ship, allowing the hammer to be brought to any point in a considerable area of the ship's bottom, without shifting.

The mounting of the hammer in gimbals permits it to be swung in any direction, making the rivet accessible from all sides, as in hand work. It has been shown that rivets can be driven with this machine at a cost not exceeding 50 per cent. of that of hand labour.

For cutting off the ends of stay-bolts in boilers of the locomotive type, a pneumatic device is employed, consisting of a cylinder about 15 inches in diameter, in which is located a piston, the rod of which projects beyond the cylinder at one end, and actuates a pair of pivoted cutting arms, a spring being provided for retracting the piston when the air pressure is removed. This machine will cut off stay-bolts up to one-half-inch diameter at a proper distance from the plate to allow for heading over, and without danger of loosening. As at first constructed, this stay-bolt cutter was quite cumbersome, weighing about 500 pounds, and requiring a hoist and two men for its manipulation; it has now been so perfected that its weight is only 75 pounds, thus permitting ready operation by one man, who can, with this machine, cut off 1800 bolts in one hour, as against 45 bolts by hand.

A pneumatic device for breaking stay-bolts is also used to profitable advant-



PAINTING CARS BY COMPRESSED AIR

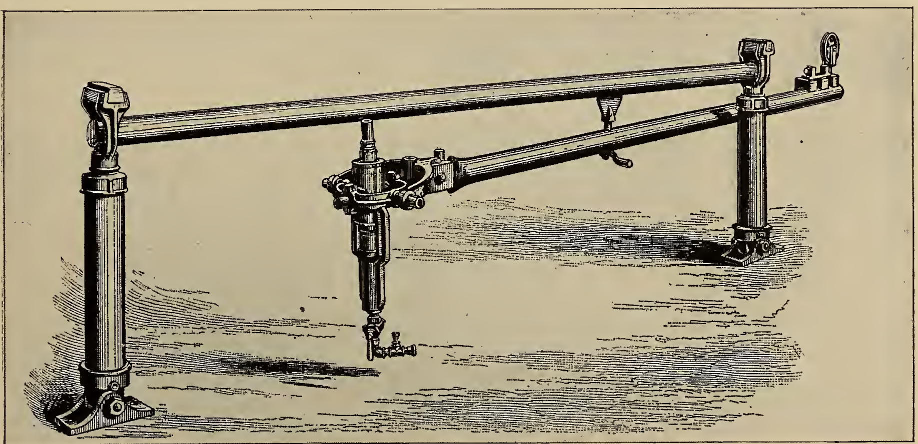
age, and consists of a cylinder provided with a leverage attachment which affords a pressure of 50 tons on the pulling bar. This bar is threaded its entire length, and has a hook at its end which engages

the bolt to be sheared. The machine is raised and lowered by a hoist, and a nut on the bar facilitates the adjustment from bolt to bolt. The entire fire-box of a locomotive boiler can be cut out with this machine many times more rapidly than could be done by hand. In swaging the ends of locomotive boiler flues, preparatory to receiving copper ferrules, a pneumatic machine is now also employed.

All who use the foundry's product appreciate well-cleaned, smooth-appearing castings, and are disposed to patronise a foundry giving especial care to this attainment in their work. It is but a comparatively short time since the pneumatic sand blast was perfected, but in foundry work it fills a decidedly important sphere in removing scale, and in cleaning off, in a thorough manner, all the burnt-on sand in places otherwise difficult to reach. In ordinary classes of work it is possible, and at the same time practicable, to clean thoroughly six square feet per minute, irrespective of the amount of ornamentation upon the casting.

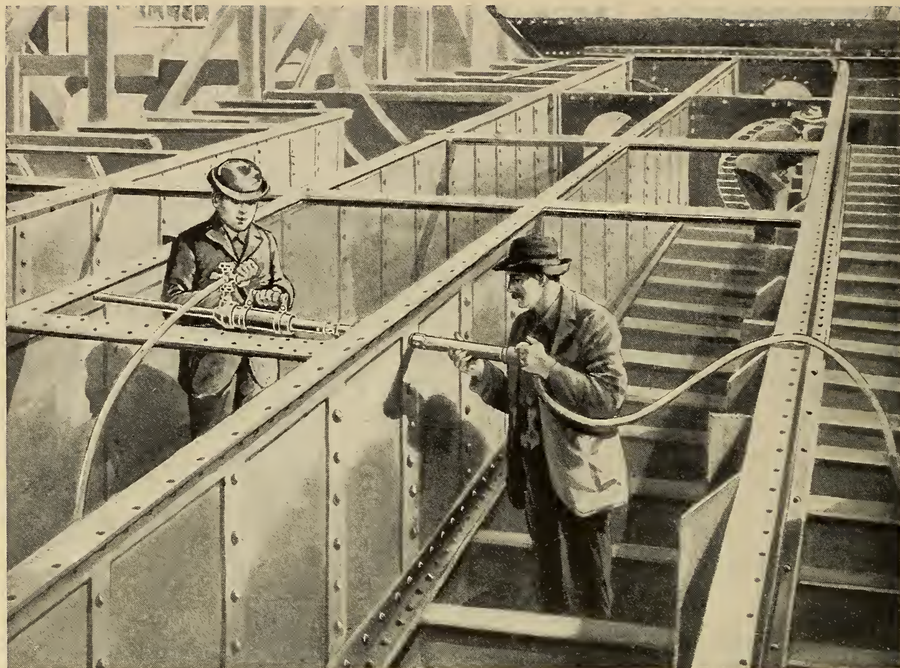
Steel castings, ordinarily very difficult to clean, yield readily to this sand blast. In one form the device used for supplying sand is similar in appearance to a vertical boiler fitted with the necessary mechanism of feed valves and sand chamber, so arranged that an air pressure of about fifteen pounds to the square inch forces the sand out through a nozzle at the end of a flexible hose. It is a peculiar feature of the sand blast that it is efficient only upon hard substances; those of a soft or yielding nature will withstand its cutting action to a remarkable degree.

In practical operation the work is accomplished by handling the nozzle in a manner similar to the manipulation of an ordinary garden hose. The sand blast naturally creates considerable dust, but is generally used in the open or in places where this is not a particularly obnoxious feature. The apparatus is readily portable, and by conveying the air supply to it, can be used at any point. The sand blast is also employed for removing old paint and scale from locomotive tenders, iron and steel ships, and for work of a similar character. It will perform with superior results the work of from six to ten men operating by hand.

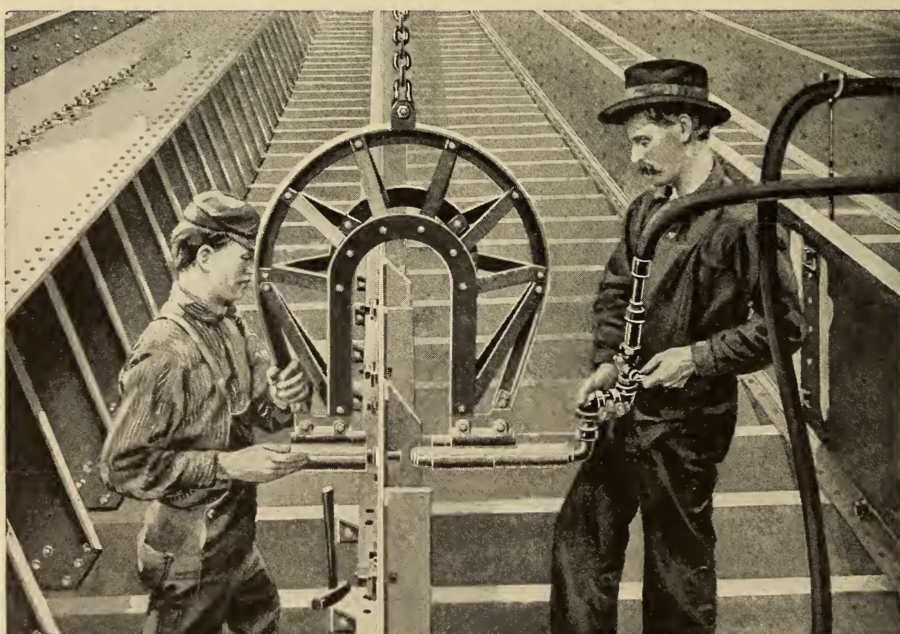


A PNEUMATIC HAMMER MOUNTED ON GIMBALS

A portable pneumatic sand sifter has many advantages over the belt-driven kind, which are located in a fixed position, necessitating a conveyance of the sand to and from them. A sand sifter fitted with the necessary mechanism, consisting of a motor of the rotary type, can be moved from place to place at



RIVETING UP LONGITUDINALS IN AN AMERICAN LAKE STEAMER WITH ONE OF THE TOOLS OF THE CHICAGO PNEUMATIC TOOL COMPANY



ANOTHER FORM OF PNEUMATIC RIVETER MADE BY THE SAME COMPANY

will, with a resultant saving of the time ordinarily required to convey many tons of sand a similar distance. This device is not unlike the sifters ordinarily driven by belt power, the chief difference being that compressed air is the actuating medium instead of the belt, with the attendant advantages before mentioned.

Another very important adjunct to the foundry is the pneumatic moulding machine. This obviates entirely the expense of stripping plates, and by using an air jet to blow sand from the pattern instead of the customary bellows and brush, much time is saved. The use of compressed air for driving this machine permits it to be moved to any part of the foundry, and it is obviously a decided economy to bring the moulding machine to the sand pile instead of wheeling tons of sand to the machine. The pneumatic moulding machine, being portable, is independent of any foundation, and can be connected to the air main by a flexible hose in any part of the foundry, which, of course, would not be possible if the machine were steam-driven. It weighs and costs but little more than a hand machine, and has all of the advantages, in point of output and size of flasks, of those driven by other power.

The product of the moulding machine is naturally greatly increased if the handling of sand and shovels is dispensed with. This can be accomplished by an air jet, which, at a pressure of 60 pounds per square inch, will lift one hundred pounds of sand per minute a height of twenty feet. By elevating the sand to an overhead bin and then conveying it through a chute or pipe to a point directly over the moulding machine, much time and labour can be saved. A slide in the pipe forms an efficient means for regulating the amount of sand served to the machine for each mould.

While on the subject of pneumatic foundry appliances, a new departure in this field, and one of considerable utility, should be mentioned. This is the pneumatic rammer, recently devised, and most satisfactorily used in one of the large shipyards, where, it is claimed, it will practically revolutionise loam moulding. This tool is portable, and consists of two vertical cylinders, held apart by stanchions and containing pistons which are actuated by compressed

A PNEUMATIC TOOL, MADE BY THE C. H. HAESELER CO., DRILLING HOLES IN BOILER WORK. THE WORK SHOWN WAS DONE SEVERAL HUNDRED FEET OUTSIDE OF THE BOILER SHOP

air; the supply of air is regulated by a simple, but ingeniously contrived valve, arranged between the cylinders.

In a rammer which the writer has in mind, the diameter of each cylinder is 3¼ inches, and the length of stroke 4½ inches. Air is supplied to the piston at a pressure of about 45 pounds, and the device strikes in the neighbourhood of 200 blows per minute, each blow of the rammer head (which is attached to the extension on the piston rod) covering an area equal to seven times that of the ordinary hand rammer. The machine is suspended from a turn buckle, which is attached to a trolley in a movable crane, enabling it to be readily used at any point.

A PNEUMATIC CHIPPING TOOL, MADE BY MESSRS. THOS. H. DALLETT & CO., PHILADELPHIA

This rammer has been employed mostly for ramming up loam moulds, and leaves nothing to be desired in the quality of work done, while in speed it will do at least twelve times as much work as can be done by hand in a similar length of time. Besides its utility in ramming up the pits around the loam moulds, it is essentially desirable for ramming up large green or dry sand moulds, or work bedded in the floor, where extra hard labour is usually required. This rammer is also useful in digging up the pit; for this work it is provided with prongs which serve to break up the sand, so that it can be readily shovelled.

In a car shop a considerable number of different types of air tools may be used, among which may be mentioned the pneumatic sand-papering machine, which has a sand-papering disc attached to the end of a rotary air motor shaft and operating between wooden shoes, which perform the same function as the block or base of an ordinary hand plane. The disc revolves at about twenty-five hundred revolutions per minute. In use, the machine is suspended from an overhead trolley, the track being about the length of the car, and, for convenience in handling, is provided with a pneumatic balance. This is a small cylinder and piston from the rod of which the machine is suspended, and the pressure of the air in the cylinder is little more than sufficient to counterbalance the weight of the machine. The tendency, therefore, is to draw up the machine to the upper part of the work. Two handles are provided, and the operator simply holds the shoes pressed against the sides of the car, at the same time lowering the machine toward the edge, the sand-papering disc being thus kept in close contact with its work.

It is the usual custom to cover about three feet in height at a time upon the side of the car for such distance as is conveniently within the reach of the operator, the whole side of the car be-

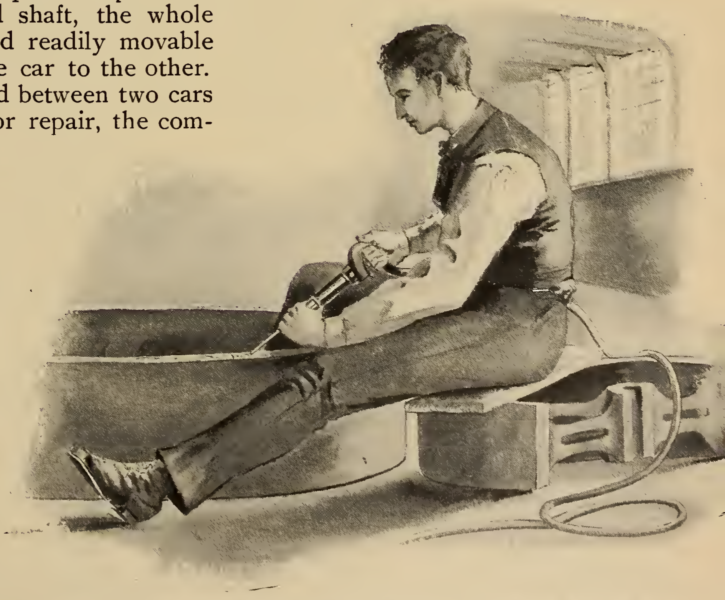
ing gone over in three installments. With this machine, both sides of a 56-foot baggage car can be finished in one day, two men operating the machine. The surface-finish produced is even and smooth, and the operator readily acquires the knack of handling the machine to the best advantage. An additional feature of merit is that rough lumber can be used for siding purposes. Coarse sand-paper is employed at first for a portion of the operation, and a finer grade of paper serves to produce the finish.

The pneumatic paint machine in car shops is everywhere a recognised factor in the equipment. This device in its various forms is so well known as to require only passing mention, but as a labour-saving agent it takes high rank among compressed air appliances. In outside bridge work, and for painting tanks, warehouses, etc., it has found ready adoption for obvious economical reasons.

A PNEUMATIC RIVETER ON SHIPYARD WORK

Another use for air in the car shop is for operating a rip saw. For this purpose the rotary air motor is again utilised, the saw being placed upon one end of an extended shaft, the whole suitably mounted and readily movable from one end of the car to the other. The rip saw is placed between two cars under construction or repair, the compressed air being conveyed to the motor through hose coupled to the main air supply pipe. Working under an air pressure of about 80 pounds per square inch, the motor is sufficiently strong for the requisite duty, and the whole arrangement has proven very useful.

In addition to the tools described, there are in use in different shops a varied assortment of special devices that have been designed to meet individual requirements. Compressed air appliances have, indeed, become a perma-



CHIPPING WITH A PNEUMATIC CHISEL, MADE BY THE UNITED STATES METALLIC PACKING CO., PHILADELPHIA

nent factor in the equipment of every modern shop, and while the time-worn statement that compressed air power is in its infancy is true no longer, it is, nevertheless, safe to prophesy that it has not yet attained its majority, and that the future will prove fruitful in the development of its still wider usefulness.

THE HEALTH CONDITIONS OF COAL MINING

By James Barrowman, Mining Engineer

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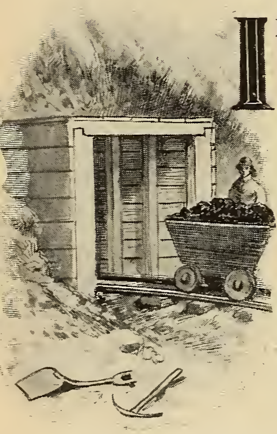


IN addressing an audience of colliers in Hamilton a few years ago, a candidate for parliamentary honours exclaimed, in a fine frenzy, that he saw death stamped on their faces. The statement was not received with that enthusiasm which the speaker no doubt expected, probably because it lacked the flavour of flattery, so agreeable to every one, and was not self-evident enough to be accepted by the audience as true. Who can tell what influence these few words had in placing him at the bottom of the poll?

That exclamation illustrates a very widespread belief, which frequently finds utterance at miners' meetings and in speeches delivered in the miners' interests, namely, that the coal-mining industry is particularly unhealthy. If it be so, it is well that the fact should be firmly established and widely known; if it be not so, the true state of the matter should be published no less widely.

It cannot be denied that coal mining is a dangerous occupation. With, perhaps, the exception of the railway industry, it is more prolific in accidents, fatal and otherwise, than any other occupation in this country. The annual reports of the inspectors of mines serve not only to keep this fact always before us, but they preserve a correct record of the nature and number of mining accidents. They also show, however, the progressive improvement that has taken place as regards safety in the occupation of the collier, and this has some bearing on the figures relating to health, referred to later on. Comparing the figures for 1855 with those for 1894, for example, as shown in Table I., it will be seen that while the number of fatal accidents has fluctuated little, maintaining an average rate over the past forty years of 1061 per annum, the output and the number of persons employed have increased almost threefold.

There is no doubt that the health conditions of coal-mining have also greatly improved within the same period. This can, of course, be said of all occupations, and of the people as a whole; but apart from this general improvement, we want to know if there are diseases peculiar to coal-mining which have the effect of shortening the life of the miner, or, if those diseases which are common to all, are aggravated by mining conditions to such an

TABLE I.

Year.	Output of Coal in the United Kingdom. Tons.	Persons Employed Above and Underground.	Fatal Accidents.	Deaths per 1000 Tons Raised.	Deaths per 1000 Persons Employed.
1855	64,453,079	242,719	*955	.015	3.9
1894	188,277,525	705,240	*1,127	.006	1.6

* Annual mean, 1061.

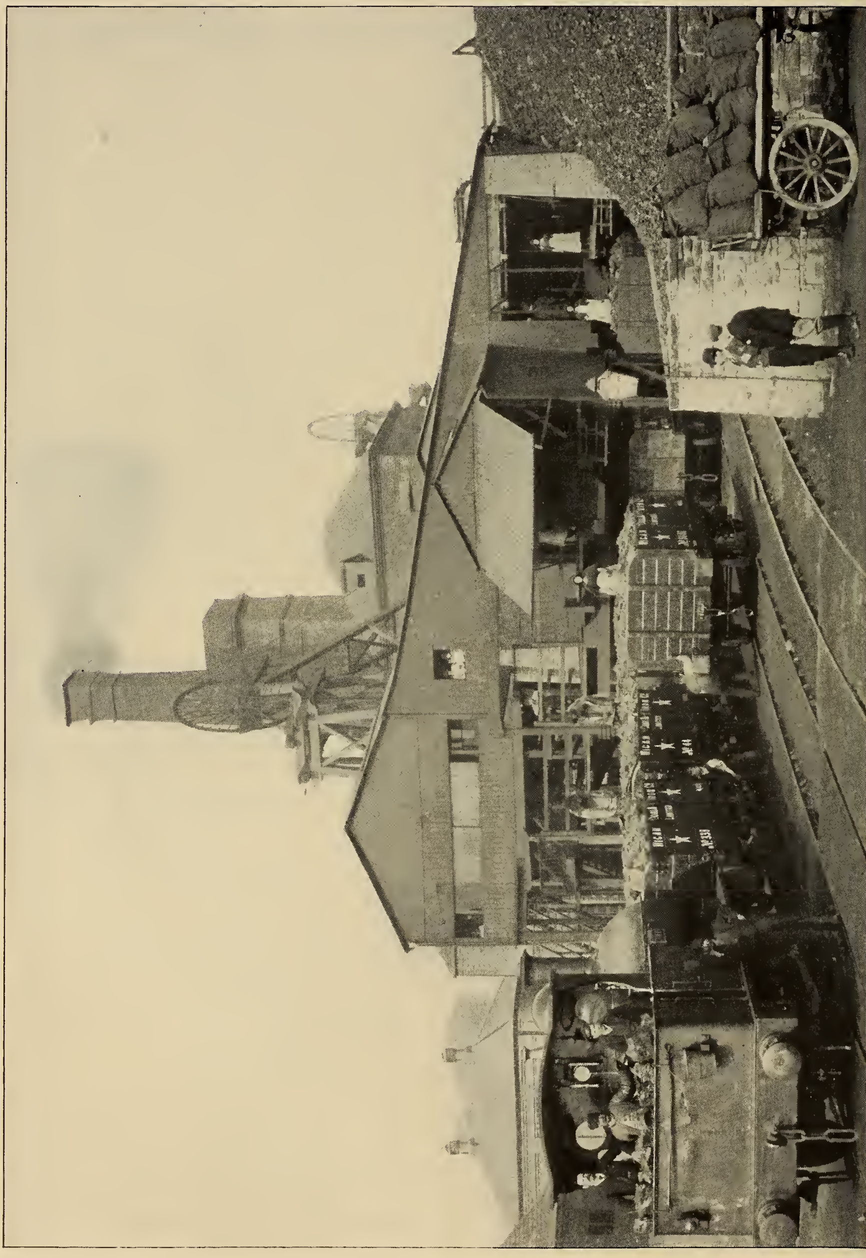
SLATE PICKING BY WOMEN

extent as to justify the statement that the coal-miner is a short-lived man. When we consider that about one-fifth of the whole male population of the United Kingdom, between the ages of 25 and 65, are miners, it will be recognised that the question is one of some consequence.

It is matter for surprise that this subject has received little attention in this country. As regards Scotland, there are no statistics published from which a comparison can be made of the health conditions of persons engaged in different occupations. Mortality tables for England and Wales have been published; but there are no statistics made up for the country as a whole, and those which are available are fifteen years old. It may, however, be safely assumed that if the conclusions arrived at after examination of the particulars collected fifteen years ago are well founded, the results would be more favourable if later statistics were available, seeing that there has been an obvious advance towards a better state of things. Apart from the statistics referred to, there are probably valuable particulars which have been collected by individual observers in isolated districts, but these appear to be few.

As to whether there are any diseases peculiar to the miner's calling, there is evidence that, with one, or perhaps two, exceptions, there are none such. These exceptions are an affection of the eyes, termed "nystagmus;" and, in a lesser degree, that disease of the respiratory organs which usually goes by the name of "miners' asthma."

Nystagmus, although not a prevalent affection, is one with well-marked symptoms, directly traceable to the posture of the collier while at work. The symptoms are oscillation, with more or less of a rolling motion of the eyeballs; giddiness, with headache, and the appearance of objects moving in a circle, or lights dancing before the eyes. In severe cases the person affected may stumble and be so much inconvenienced



PROSPECT PIT OF THE WIGAN COAL AND IRON COMPANY, LTD., WIGAN, ENGLAND

as to be obliged to stop work. Dr. Simeon Snell, of Sheffield, has given this disease special attention for about twenty years, and has published the results of his investigations, which show beyond all reasonable doubt that nystagmus is confined almost entirely to those underground workmen who are engaged in holing or under-cutting the coal, and is due to the miner's habit of looking upwards, above the horizontal line of vision, and more or less obliquely while at work lying on his side. It has been observed also in firemen and others who have occasion frequently to examine the roof, turning the eyes obliquely while doing so. Any other occupation in which the person may habitually turn the eyes upwards and sideways will induce nystagmus; but such cases are so rare that this trouble may be regarded as one peculiar to mining. Turning the eyes downwards yields temporary relief; but there seems to be no permanent cure for it except abandonment of the kind of work that gave rise to it.

It has been alleged that the use of safety-lamps in the mines, giving less light than the open candle or lamp, has aggravated this disease; but careful and long-continued observations have proved that there is no connection between the use of safety-lamps and the alleged increase of nystagmus. The number of miners is on the increase, and greater attention has been given of late to this affection than formerly, which circumstances sufficiently account for the supposed relative increase in the number of cases. Other specialists in this country and on the Continent confirm the conclusions of Dr. Snell.

AN AMERICAN COAL MINERS' VILLAGE

The disease, called miners' asthma, with which a characteristic black spit is associated, cannot be said to be special to mining in the same sense as nystagmus is, as there are other occupations in which a similar disease is prevalent, such as those of quarriers, masons, and pottery makers; still the conditions of underground occupation appear to be conducive to the extension of this and related diseases of the respiratory organs. It is clear to an ordinary observer that, within the last quarter of a century, there has been a great improvement in coal-miners in this respect, and that those who suffer from diseases of the respiratory organs

UNDERCUTTING COAL, WHICH LEADS TO THE EYE DISEASE KNOWN AS NYSTAGMUS

are relatively fewer now than they were twenty-five years ago. We do not require the evidence of vital statistics to convince us of this, and we can have no difficulty in attributing this better state of things to the great improvement in ventilation effected within the time mentioned.

But it is from a comparison with the workmen in other occupations that the most definite results as to the health conditions of mining are to be got. The information available for the purpose is contained in a series of tables prepared by Dr. Ogle, the superintendent of statistics in the general register office, from particulars collected at the census of 1881, and from similar figures collected by his predecessor, Dr. Farr, at earlier dates. In Dr. Ogle's tables, six coal-mining districts in England and Wales are selected, namely, (1) Durham and Northumberland; (2) Lancashire; (3) the West Riding of Yorkshire; (4) Derby and Nottinghamshire; (5) Staffordshire; (6) South Wales and Monmouthshire. It is to be regretted that there are no published statistics for Scotland.

Dr. Ogle gave evidence, in 1892, before the Royal Commission on Labour, and then submitted a series of tables, an abstract of one of which is given in Table II. This shows the number of deaths that took place annually in the years 1880, 1881, and 1882, in 116,261 males of each occupation stated, of whom 75,396 were between 25 and 45, and 40,865 between 45 and 65 years of age. This population was selected as being that in which 1000 deaths of clergymen occurred annually, being the lowest death-rate of all. Those described as coal-miners include aboveground as well as underground workers in connection with collieries. The results shown by Table II. are very different from what popular belief would have led us to expect.

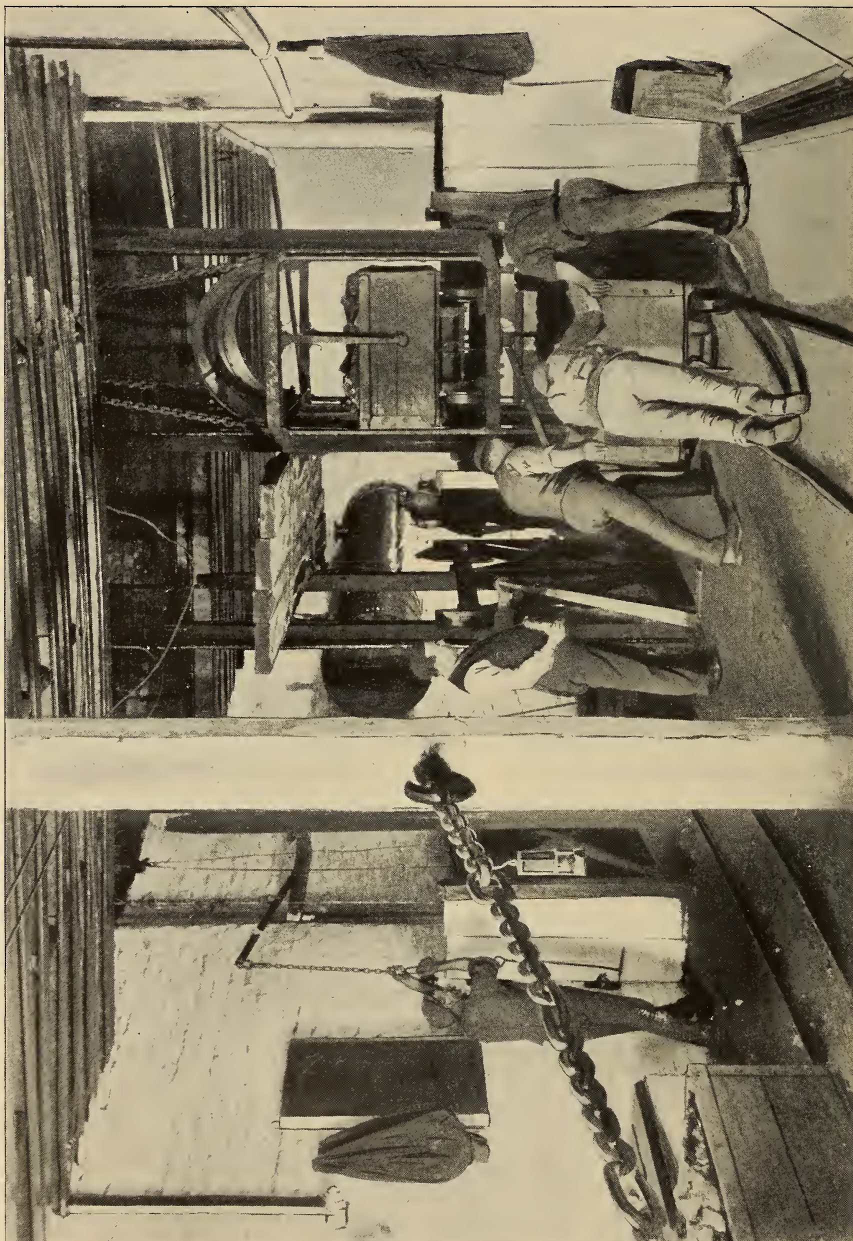
Comparing the deaths of coal-miners in the six districts referred to under the several headings in Table II. with the deaths of all males of a corresponding age in England and Wales, we find that, with only two exceptions, the death-rate of coal-miners is the lower. These exceptions are accidents and diseases of the respiratory organs. We should ex-

pect these two causes of death to rank high with miners; but the comparison in the case of the other causes of death is so favourable for miners that, on combining the figures for all causes of death, including accidents and diseases of the respiratory system, the death-rate of the coal-miner still stands lower than the average of the country. It is noticeable also that, if the coal-mining districts be taken separately, the deaths of miners in each, with the one exception of South Wales, are less than the deaths of all males in the same district.

In case it may be thought that comparison with all males is not a fair one, let some of the occupations be selected to which dust or high temperature, or both, are incident, and still the comparison is in favour of the coal-miner. The baker, the blacksmith, the mason, the wool-manufacturer, the quarrier, the file-maker, and, notably, the earthenware manufacturer, have all a much higher death-rate; indeed, we have to go to the occupations which are recognised as the most healthy to get a close agreement with the coal-miner.

In drawing attention to the high death-rate in miners from diseases of the respiratory system as compared with that from phthisis, Dr. Ogle refers to the somewhat loose way of certifying death, and expresses the opinion that many deaths registered under the name "miner's phthisis" should really be under one or other of the diseases of the respiratory organs, and that there should be an addition to the number of deaths from the latter and a corresponding reduction in the number of deaths from phthisis. What this addition should be it is impossible to say; but although it were considerable, there are still, as shown in Table II., a number of occupations having a higher death-rate from diseases of the respiratory organs. If, as suggested by Dr. Ogle, an addition should be made to the figures in the column under diseases of respiratory organs, and a corresponding deduction from those under phthisis, then the latter will occupy a surprisingly low place relative to deaths from that cause in other occupations. As it stands in Table II. there are few occu-

HEWLETT PIT OF THE WIGAN COAL AND IRON COMPANY, LTD.



AT THE BOTTOM OF THE PIT

TABLE II.—COMPARATIVE MORTALITY OF MALES IN ENGLAND AND WALES, FROM 25 TO 65 YEARS OF AGE IN DIFFERENT OCCUPATIONS FROM ALL AND SEVERAL CAUSES, 1880–81–82.

OCCUPATION.	Comparative Mortality from All Causes.	Diseases of the Nervous System.	Phthisis.	Diseases of the Respiratory Organs.	Liver Diseases.	Other Diseases of the Digestive System.	Alcoholism.	Accident.	All Other Causes.
Clergyman	1,000	180	116	116	28	49	4	11	496
Physician	2,018	334	222	250	183	74	25	84	846
Farmer	1,135	146	185	178	74	54	11	59	433
Agricultural labourer	1,261	144	219	281	36	77	2	50	433
Gardener	1,077	113	218	200	32	40	4	43	427
Fisherman	1,433	146	194	162	58	62	7	273	531
Commercial traveller	1,705	250	432	264	110	47	41	65	496
Innkeeper	2,736	360	531	390	432	67	99	81	776
Grocer	1,387	192	300	209	94	56	18	25	493
Draper	1,588	196	541	232	63	68	14	41	433
Butcher	2,104	250	470	375	173	59	41	63	673
Baker	1,723	245	381	334	83	47	27	38	568
Tailor	1,890	259	513	335	86	76	20	32	569
Shoemaker	1,658	219	457	282	58	54	7	31	550
Printer	1,926	162	829	295	50	58	5	43	480
Earthenware manufacturer	3,133	252	851	1,160	88	61	14	43	664
Wool manufacturer	1,856	228	462	369	65	72	7	49	604
Mason	1,743	158	453	362	54	61	9	81	565
Plumber	2,162	300	442	333	86	68	22	131	780
Carpenter	1,475	160	367	239	65	54	7	68	515
File maker	2,998	471	779	629	74	58	5	11	971
Blacksmith	1,750	171	388	367	56	63	14	88	603
Miner, Durham and Northumberland	1,570	158	243	219	59	61	7	353	470
All males, Durham and Northumberl'd	1,723	205	320	279	65	74	23	176	581
Miner, Lancashire	1,671	149	225	412	32	58	5	356	434
All males, Lancashire	2,246	255	450	552	76	81	31	147	654
Miner, West Riding	1,388	108	200	309	38	56	2	290	385
All males, West Riding	1.854	212	423	383	67	70	13	113	573
Miner, Derby and Nottinghamshire	1,320	115	212	248	31	61	7	293	353
All males, Derby and Nottinghamshire	1,522	178	299	266	74	59	16	118	512
Miner, Staffordshire	1,671	146	183	468	36	50	2	309	477
All males, Staffordshire	1,811	210	313	406	77	70	16	135	584
Miner, South Wales & Monmouthshire	1,944	108	299	527	43	63	9	412	483
All males, S. Wales & Monmouthshire	1,809	174	363	376	67	70	13	221	525
Mean for coal-miners	1,603	135	227	353	42	58	5	338	445
Miner, ironstone districts	1,500	92	254	371	25	25	14	371	348
Miner, Cornwall	3,308	210	1,241	824	72	101	4	210	646
All males, Cornwall	1,595	178	365	297	49	65	7	106	528
Quarrier	2,018	149	554	493	45	68	9	266	434
Hawker	3,379	372	854	755	85	119	34	95	1,065
All males, England and Wales	1,799	214	396	327	70	68	18	121	585

pations with greater immunity from phthisis than coal-mining, and if the figures be reduced we must turn to the very healthiest occupations, such as that of the fisherman, the farmer, and the gardener for an equal comparison.

The comparative immunity of coal-miners from phthisis has been the subject of observation by medical men, both in Great Britain and on the Continent. Dr. Nasmyth found that in the parish of Beath, in Fifeshire, for the twelve years from 1876 to 1887, the death-rate from phthisis was 1.01 per 1000 for miners, as compared with 1.72 for females and 1.33 for both sexes. The opinion has been firmly expressed by at least one Continental writer that the coal-dust inhaled into the lungs by the coal-miner has a preservative influence, and to some extent prevents consumption. An examination of coal-dust under the microscope shows that the particles are rounded, and on that account much less likely to irritate the lungs than the heavier and more angular dust made by the mason and the quarrier.

The death-rate of coal-miners from alcoholism is particularly low, which goes to show that the occasional drinking to excess indulged in by many of them is less deleterious in its effects than the more frequent tippling of men in some other occupations.

In comparing the figures for the six

A HUNGARIAN COAL MINER'S FAMILY IN THE PENNSYLVANIA REGIONS

SOME TYPICAL AMERICAN MINERS' DWELLINGS

several coal-mining districts, one is met with differences of which the cause is not apparent. South Wales and Monmouthshire have a much higher death-rate than any of the others, and this suggests the inquiry, what relation will Scotland bear to these districts? The workings of the collieries in Scotland being in general not so extensive nor so deep as those in England and Wales, it is probable that, on the whole, the underground air is purer, and the extremes of temperature are not so wide in Scotland as in England and Wales; and it may be safe to assume that the average figures of the six coal-mining districts already referred to will form a fair basis for the mines of Scotland.

A VIEW IN BABBINGTON COLLIERY, NOTTINGHAM, SHOWING STEEL GIRDER PROPS MADE BY MESSRS. WM. FIRTH LTD., LEEDS, ENGLAND. THESE PROPS ARE MADE OF $5 \times 4 \times 3/8''$ STEEL, WITH THE WEB CUT AWAY AND ENDS TURNED OVER

Because of the very favourable aspect in which the figures on Dr. Ogle's table place the coal-miner as compared with men in most other occupations, we are disposed to criticise his table with the view of finding out whether the method of compilation is sound. A few objections may be mentioned, some of which Dr. Ogle has anticipated and answered.

It is obvious that, to a certain extent, coal-miners are picked men. Those who are lame, blind, and otherwise infirm, will not choose this occupation; and those who, by accident, are disabled for active exertion, must leave it. For these reasons the figures in the table will tell too favourably for the coal-miner, seeing that the population, as a whole, includes all infirm persons. But the same may be said of several of the occupations named on the table, such as quarriers and blacksmiths, and yet these have a higher death-rate than the miner.

The death-rate from accident being so high in the coal-mining occupation, there must be a corresponding decrease in the number of deaths from natural causes. To this extent the table shows too favourably for the miner from a health point of view; but, as has already been noticed, the deaths from all causes,

including accident, are, in the case of coal-miners, less than those of most other occupations enumerated in the table. Moreover, we have seen that the deaths from accident have been proportionally much reduced during the last forty years. The small error due to this cause must, therefore, be of less account in each succeeding census.

Another point that suggests criticism is that regarding the period of life embraced in the table. A coal-miner has ten years of his working life past at the age of twenty-five, and many leave pit-work before the age of sixty-five. It may be answered, however, that whilst that is so, the same may be said of other workers mentioned in the table; and that, especially with those industries with which one would most readily form a comparison,—that is, labouring occupations and trades,—they are substantially on an equal footing.

It has to be borne in mind that no mortality-table can present the facts with absolute accuracy. At the same time there seems no good reason to doubt the general reliability of the table as a statement of relative health conditions.

On the whole, therefore, we have good grounds for regarding the occupation of the coal-miner as one of the healthiest; and even after including deaths from accident we see that the mortality among coal-miners is less than that of most manual occupations. In the "Report of the Royal Commission on Labour," 1892, the opinion of the committee on the subject is stated as follows:—

"The weight of evidence seems to be against the idea that coal-mining is an unhealthy occupation, even when allowance is made for the probability that weakly men either avoid or soon abandon it."

There are several circumstances which may be regarded as contributing to the evidence that the health conditions of the coal-miner are favourable.

In the first place, the underground temperature is equable, and, generally, not uncomfortably high. That these are favourable conditions receives some corroboration from the fact that

CLEANING COAL

EATCOCKS PIT OF THE WIGAN COAL AND IRON CO., LTD.

pit ponies, although confined underground for years, thrive and keep up in flesh and appearance even better than when worked on the surface. The regular temperature of the air seems to more than make up for the want of daylight.

There is no doubt an excessively high temperature, especially if accompanied by a moist state of the air, is bad; but the former is confined to the very deep mines, and a conjunction of the two is not common. The sudden change from one extreme of temperature to another, when the miner comes out of the pit on a winter's day, is what most readily leads to diseases of the respiratory organs, and should be provided against more effectually than is the custom.

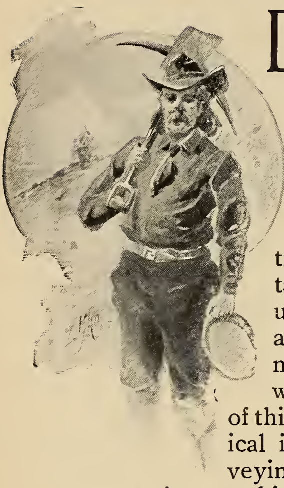
In the second place, the bulk of the coal-miners live in rural communities, and have the benefit of fresh air.

Thirdly, the coal-miner's working day is a comparatively short one, and he seldom works every day in the week. The Scottish collier has always had a hankering after a weekly holiday. As far back as the year 1641 an act of the Scottish Parliament was passed, ordaining colliers and other colliery workmen to work all the six days of the week, the reason given being that they had been in the habit of taking frequent holidays, which they spent in "drinking and debauchery, to the great offence of God and prejudice of their masters." Like many other of the early acts, this one was pretty much ignored; at any rate, we find that towards the end of the next century five days was the ordinary week's work in the collieries.

Good as things are, we hope to see them better. We cannot entirely do away with all the causes of death and disease, but strenuous efforts are being made to lessen their effects. The composition of the gases met with in mines, and their effect on the human system, are receiving most careful attention. Ventilation has been brought to a high state of efficiency; the resources of science are taxed to provide an explosive that can be used without the risk of igniting fire-damp, and better dwellings and improved sanitary arrangements are now the rule. All these tend towards the bettering of the health conditions of coal-mining.

THE PELATAN-CLERICI PROCESS FOR THE EXTRACTION OF GOLD AND SILVER

By E. Gybbon Spilsbury



DURING the last decade the treatment of gold and silver ores, and especially those generally classed as refractory ores, has been brought to such a high state of perfection that deposits containing such small values as $3 and $4 (12 and 16 sh.) a ton are now being successfully worked. While much of this is due to the mechanical improvements in conveying, crushing, and concentrating machinery, the chief agent has been the successful introduction of the chemical, and, later on, the electrochemical processes for dissolving the gold and silver contained in the ores, and their subsequent precipitation from the liquid solutions.

While there are a great number of active solvents known to chemists, both for gold and silver, general practice has so far confined itself to only two, chlorine and potassium cyanide, for the reason probably that both of these solvents are obtainable at a comparatively low cost, and also because they are probably the most active agents of all.

Quite a number of processes have been invented and patented from time to time, all based more or less on the use of one or the other of these solvents, combined with special mechanical arrangements for handling the material to be treated, and further chemical treatment for the recovery of the values from the solutions.

The process which is the subject of this article is an invention of comparatively recent date, which seems to combine advantages based on thoroughly scientific principles, and promises to come into very general use as its advantages become more generally understood. The Pelatan-Clerici process must be classed as an electro-metallurgical improvement on the regular cyanide process. Without going into the historical details of its development, the present system, generally adopted, consists in the treatment of the previously crushed ore, in circular tanks, with a cyanide solution, in the presence of a bath of mercury, and under the influence of an electric current.

The details of the mechanical construction of these tanks may be varied somewhat to meet local requirements, but in general, the tanks are built nine feet in diameter and five feet deep. The bottom of the tank is covered with a copper plate, over which is a bath of mercury. This copper bottom is connected with one pole of the electric current, which, through it, is communicated to the mercury bath, thus making the latter the cathode.

A vertical shaft, having a series of arms and stirrers, fastened to iron plates, is suspended in the tank in such a manner as to revolve in a plane removed only a few inches from the mercury bath. This shaft, and through it the iron plates, is connected with the opposite conductor from the electric generator, and these plates become the anodes. The ore, being previously crushed to the desired fineness, and mixed with about an equal weight of water, is run into the tank, the shaft and stirrers being kept all the time in motion. A certain amount of salt is then added, depend-

ing somewhat on the character of the ore, and the electric current is turned on.

The ore in this condition is kept in agitation for a given length of time, generally three or four hours, after which the required amount of potassium cyanide is also added, and the agitation continued until the extraction of the values is completed. The pulp is then discharged through a valve just above the bath of mercury, and the vat is again ready for the new charge. After a certain number of charges have been passed through, the mercury is drawn off through the bottom, the amalgam strained from it, and the copper plate scraped for the amalgam adhering to its surface. This, in brief, is the general method of procedure.

Now let us look into what really takes place in the vat! In the first place, it is aimed to crush the ore to such a degree of fineness as will practically liberate the particles of gold, or at least leave some portion of them exposed to the rapid action of the solvent. As this process, unlike the regular cyanide or chlorination process, does not depend on the filtration of the gold solution from the pulp, it is possible to carry the crushing of the ore to any desired fineness, and also to treat clayey or slimy ores of every description which could not be treated by the other methods. The reactions during the first stage of the operation, viz., the period before the addition of the solvent, should, I am inclined to think, be considered as more mechanical than electro-chemical, although there is no question that the electric current serves a very decided object even during this part of the process.

As we have seen above, sodium chloride is added to the pulp in agitation, the primary object of this addition being to increase the electric resistance of the semi-liquid mass. Some authorities on the subject claim that the electric current at this stage decomposes the sodium chloride, freeing chlorine in sufficient quantities to act as a solvent for the gold, while the resultant sodium combines readily with the mercury, forming sodium amalgam.

While this would, of course, be the reaction in a clear salt solution containing fine gold in suspension, it is hardly conceivable in practice, when we take into consideration the almost invariable presence in the ore of iron salts of a more or less soluble nature, which would naturally be attacked by the chlorine long before the gold would, and which would, at any rate, cause the reprecipitation of the gold as soon as it is formed. This double reaction may take place also, to a certain degree; but I hardly think it is carried on to an extent to be considered as part of the process, nor do I consider that it would be advantageous to endeavour to promote this action, as might be done by an increased electric power, for it would be a far more expensive method of dissolving gold than by means of the plain cyanide solution. The cost for the power necessary for sufficient decomposition of the saline solution to dissolve the gold, and also neutralise the iron salts in the charge, would be so great as to be almost prohibitive. In practice the current used never exceeds 8 to 10 volts, with a volume of from 75 to 100 ampères.

That with this current a slight decomposition of the sodium chloride really takes place is unquestionable, and while we may doubt the effect of the liberated chlorine on the gold, there is the assurance that the sodium is amalgamated by the mercury, the surface of which is thereby kept clean and bright and in better condition to catch the gold than would otherwise be the case. To this extent, therefore, the first stage of the process may be considered electro-chemical.

The real object of the first stirring, before the addition of the solvent, is to allow the coarser particles of gold to settle by gravity through the pulp, and be caught by coming in contact with the mercury. It, further, has the effect of brightening the surface of the gold particles, thus accelerating the subsequent action of the mercury and the solvent to a considerable extent. During this time, also, the ferric and other sulphates, always present to a certain ex-

tent, are dissolved, and the resultant acid solution can be neutralised by the addition of lime, or some active oxidising agent, the effect of which is to practically render all the metallic salts insoluble in the cyanide solution, and thereby reduce to a minimum the amount required for dissolving the gold.

The second stage of the operation begins with the addition of the cyanide solvent, and during this final period the process is purely an electro-chemical one. The gold, being dissolved by the cyanide, is deposited on the face of the mercury cathode by means of the electric current. This part of the process is continued until samples taken from the liquor show no further trace of gold.

Now as to the commercial aspects:—The invention appears to the writer to compare very favourably with any of the various processes now so generally used. It has its defects and limitations, as have all the others; but, on the other hand, it has advantages that no other single process has, and combines nearly all the good features claimed by any of the others.

It will treat all ores that can be treated either by direct amalgamation, chlorination or cyaniding, and will extract a larger percentage of the values than either of these processes. In addition, it can be expected to successfully treat a large number of ores which are intractable to the others, or which require a special treatment, such as roasting, before they become amenable to treatment.

Plain amalgamation fails practically in the presence of sulphides, and with ores of a talcose or clayey nature. Cyaniding, depending, as it does, on filtration, is not possible with ores of a clayey or talcose nature, nor with ores containing any appreciable quantity of fines or slimes, nor is it successful on ores containing coarse gold, or a large percentage of silver. Chlorination, while giving remarkable results of extraction on ores specially adapted to that process, requires an absolutely perfect roasting of all sulphide ores before the chlorinating begins, and has the further defect of not extracting any coarse gold present in the ore, nor saving any of the silver values.

The Pelatan-Clerici process, on the other hand, as we have seen above, is specially adapted to the treatment of ores having all the objectionable qualities mentioned. The finer the ore, the better will be the extraction results. The coarse gold, finding its way by gravity through the pulp, comes in contact with the mercury and is immediately saved.

The percentage of silver saved, while possibly not always so great as the percentage of gold, is still far in excess of that saved by other processes, and generally exceeds 75 per cent. of the assay value. While the strength of the solvent liquor necessary is probably greater than that used in the ordinary leaching vats, the consumption of cyanide per ton of ore treated by the new process is not so much more than that used by the other processes as to counterbalance the advantages of the comparative rapidity of extraction and the higher percentages of yield obtained. Indeed, it is a question whether any excess of cyanide is required on such ores as are specially adapted to the ordinary leaching process, and where no silver values are required to be saved.

We all know, at least those do who have had experience with the leaching processes, the many objections to, and troubles arising from, the zinc shaving process of precipitation, and the difficulties and losses attending the final treatment and refining of the bullion. In the Pelatan-Clerici process none of these are to be contended with. The values being recovered in the form of amalgam, no further treatment than the distillation of the mercury is necessary, and this is a simple process, perfectly well understood by every miner or mill-man, and requiring little or no special skill.

There are some defects and disadvantages inherent to this system, but they are not insurmountable, or of very great importance. The chief one of these is the fact that the size of the vats must necessarily be somewhat limited, as it is not practicable to increase their size very materially beyond the nine

feet diameter generally used, owing to the difficulty, first, of maintaining rigidity in the stirrer arms if their length is much increased; and secondly, of preventing the centrifugal action counteracting the gravity forces and retarding the deposition of the coarse gold if the diameter of the vat is much greater than twice the height of the column of the pulp. This results in necessitating the adoption of a much smaller unit of treatment than that established by the ordinary leaching system, and in so far is a disadvantage.

The use of very large tanks makes it possible to adopt mechanical methods for charging and discharging them, thus reducing the labour cost to a minimum. When smaller units are used, more frequent operations are required, and consequently the labour cost is somewhat increased. On the other hand, it would appear that the Pelatan-Clerici process could, and should, be used to very great advantage as an adjunct to the regular cyanide process for the precipitation of the gold from the solutions instead of the zinc shavings or zinc dust method now in use. The percentages of gold recovered would be considerably increased, the gold would be recovered in a much better condition, and a great saving in time would be effected.

The two processes are not inimical to one another, but should be worked with one as the complement to the other. By so doing, all the slimes made by crushing would not be lost, but would be treated in the Pelatan-Clerici plant as well as the solutions from the leaching vats.

To sum up, the advantages claimed for the Pelatan-Clerici process over all other processes may be stated as follows:—

1st. Greater range of ores adaptable to treatment.

2d. Possibility of treating clayey and slimy ores not adapted to percolation filtration methods.

3d. Saving of a very large percentage of the silver as well as the gold from the ores.

4th. Recovery of the gold in the form of amalgam instead of the difficult compounds resulting from the zinc precipitates.

5th. The recovery of coarse gold as well as fine, which cannot be done by either the cyanide process or by chlorination, except at great expense for solvent and greatly increased time required.

One of the best proofs that the claims made by the inventors of this process are based on sound facts is demonstrated by the great success which has met its introduction at the celebrated Republic Mine in Washington, U. S. A.

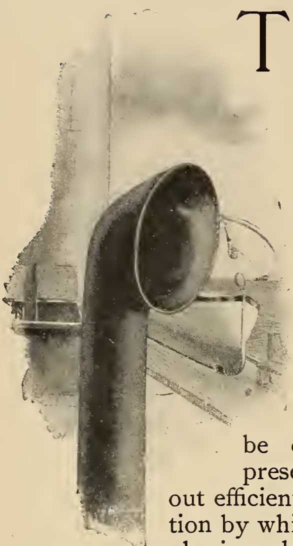
The ore in this mine is a peculiar one, and while containing very high values, was not profitably amenable to treatment, either by the regular cyanide process, or pan amalgamation, both of which were tried and failed. The ore is of a talcose nature, impervious to filtration when crushed down to a size sufficient to liberate the gold, and of such a dense character, when not crushed fine, as to defy the solvent action of the cyanide solution.

The best extraction by the cyanide process on this ore did not exceed 55 per cent. of the gold alone, with none of the silver, while by pan amalgamation not more than one-third of the values were extracted. The published report from the mine for the last three months show a saving of 90 per cent. of the assay values by the Pelatan-Clerici process, which has enabled this mine to become one of the large dividend payers of the American Northwest.

The electro-metallurgical treatment of gold ores on a large scale is still in its infancy, and it is more than possible that the Pelatan-Clerici process may suffer the fate of so many pioneer inventions and be superseded by other improved methods, or more probably that its own inventors will, little by little, so improve it as to overcome the difficulties now existing in handling very large tonnages at a minimum cost; but in the present state of the art the process is, undoubtedly, the most economical for treatment of both high and low grade ores in quantities up to one hundred tons per day.

THE VENTILATION OF STEAMSHIPS

By Stephen H. Terry, M. Inst. C. E.



THERE is hardly any class of cargo carried which would not be the better for ventilation when that ventilation is under complete control. Were it universal, damaged cargoes, dead cattle, bunker and hold explosions would be unknown.

The colliery industries could not be conducted on their present large scale without efficient and reliable ventilation by which the whole atmospheric and gaseous contents of a mine are frequently changed. In coal mines there are many and great natural obstacles, apart from financial considerations, which render the problem one of great difficulty, for the depths and horizontal distances which the air has to travel are large, and in order to bring it to the working faces it must be divided up into numerous streams and prevented from making short cuts. It has, indeed, to be treated almost as a wayward child, the word "don't" being represented by a brattice, door or wall, by which it is trained in the way it should go.

In the early days of coal mining, when the depths attained were only a few hundred feet, the need for ventilation was not so great, and at a later date, when some sort of ventilation was necessary, the sight of a chimney gave the idea of the crudest form of colliery ventilation and produced the furnace system of ventilation with its many disadvantages and dangers. One of the disadvantages is that this system gives the best results in cold, dry weather with high barometer, whilst the greatest need for ventilation exists in hot weather and when the barometer is low.

In the case of collieries the gases to be dealt with are of two classes,—one lighter than air, the other heavier. Thus, fire damp has a specific gravity half that of air. This gas is explosive when mixed with air in proportions ranging from 1-13 to 1-5. Carbonic acid gas and carbonic oxide, on the other hand, are both heavier than air (about 1½ times in the case of the former), and are fatal to life if the proportion exceeds about 0.08. These gases, owing to their specific gravity being different from that of air, do not mix freely with it, although, having once mingled, they are not easily separated. In consequence of their different specific gravity they accumulate in certain spots, the carbonic acid at the lowest levels and the carburetted hydrogen, or fire damp, at the highest, refusing to be readily dislodged by currents of air flowing over and under them, respectively, and making no efforts to move from the localities where they have accumulated.

The basis of the successful ventilation of collieries is the adoption of two distinct openings, connecting the workings with the surface. One of these is a downcast shaft, and through it the air supplied to the pit passes. The other is an upcast shaft, and through it flow the entire gaseous contents of the pit, consisting of the air which has passed down the downcast shaft, and with it the gases produced in the pit. These shafts, upcast and downcast, are perfectly distinct and separate from one another, and are so carefully disconnected that, although in some mines they may be close together, the streams of air can flow from one to the other only after having traversed the entire workings of the pit.

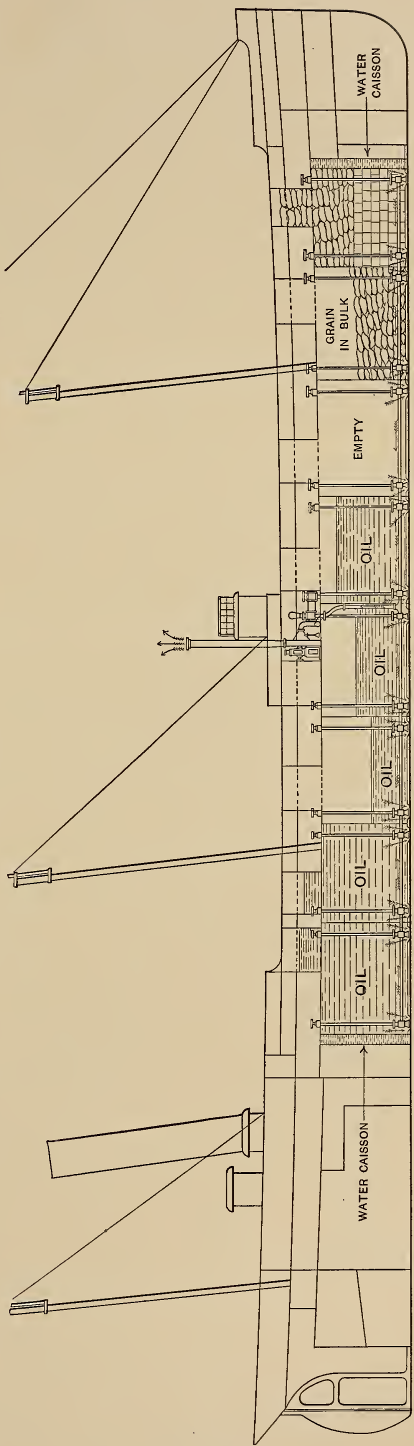
The author's experience in the ven-

tilation of coal mines led him to believe that successful ventilation of ships would only be accomplished on similar principles, and a system, modelled accordingly, was installed on a number of oil steamers.

The source of danger in bulk oil boats is that after the cargo has been pumped out, vapour of great density is produced by the evaporation of such of the liquid as remains adhering to the surfaces of the interior of the vessel, this vapour having a density three and a half times that of air, and twice that of carbonic acid gas.

Various attempts at oil-boat ventilation have been made by blowing air down into the empty tanks, but in consequence of the great density of the vapour very little success has attended these efforts. With colliery practice in view, however, it became evident that the most efficient ventilation (per cubic foot of air or vapour dealt with by the fan) would be secured if suction, instead of pressure, were adopted when dealing with vapour of high specific gravity, the reason being that the vapour, being heavier than air, is found at the lowest parts of the ship, and in a dense condition, and that when suction by a fan is employed the fan draws the vapour down as water in a well is lowered by pumping. The fan is engaged solely in passing dense vapour, whilst any remains, and will draw fresh air only after complete removal of the heavy vapour.

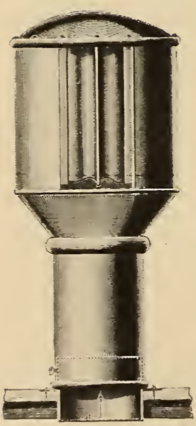
As the capacity of any fan is limited to so many thousand cubic feet per minute, it is clear that complete removal of heavy vapour will be more readily accomplished when the fan is taking its full of vapour rather than when it is blowing pure air into a vessel, a large portion of which air would find its way up the nearest hatchway. When suction is employed, however, and heavy vapour is being dealt with, the fan is occupied with vapour only as long as any remains in the ship, after which, if the fan be still run, pure air will be drawn with such admixture only of petroleum vapours as the temperature and flashing point of the oil may determine.



LGONITUDINAL SECTION OF AN OIL BOAT ILLUSTRATING A SYSTEM OF VENTILATION DEVISED BY MESSRS. TERRY AND FLANNERY

In an oil ship there are oil mains extending into each tank, a convenient tank size in 5000-ton ships being about 400 tons. The oil mains serve to admit the oil, to prevent cascade action, and consequent waste and danger, and also serve as suction mains for the general removal of the oil. In modern vessels they are generally 10 inches in diameter. This size, although ample for oil, is small for air, but the difficulty has been got over by making fans of very high efficiency. A good size is 6 feet in diameter and 10 inches wide on the face. The fans used by the author have a single inlet and reducing nozzle, and are capable of running continuously for six weeks at 500 revolutions a minute, giving a water gauge up to 12 inches and a theoretical air velocity of 13,738 feet per minute. This, with a pipe having an area of one foot, would give, neglecting friction, the same number of cubic feet of air.

The 10-inch pipes, however, have an area of only half a square foot, and consequently the rate at which the air passes is about 5000 cubic feet per minute. But it is possible to get a water gauge with this fan such that 8000 cubic feet per minute would pass. This rate would entirely change the atmospheric contents of a 5000-ton oil boat in less than half an hour, and as it is rarely necessary to ventilate the whole ship at one time, the whole ventilating power may be concentrated in the tanks more recently pumped out. In this way the contents of a 400-ton tank may be completely changed once in two minutes.



A BOYLE "AIR PUMP" UPCAST VENTILATOR

This system has been jointly patented by Mr. F. Flannery and the author, and consists in ventilation by suction through the pipes provided for the discharge of cargo.

With such a forced-circulation system in use, oil in bulk has been safely carried outwards, whilst the return voyage has been made with ordinary cargoes, such as rice, coffee, tea and spices, and these goods have been carried without taint in the tanks which, a few hours previously, held oil in bulk. Letters have been received speaking of the excellent condition in which the goods arrive in consequence of the effective ventilation which has prevented that bane of shippers—sweating, — by which heavy losses occur annually in the grain trade.

A BOYLE DOWNCAST VENTILATOR

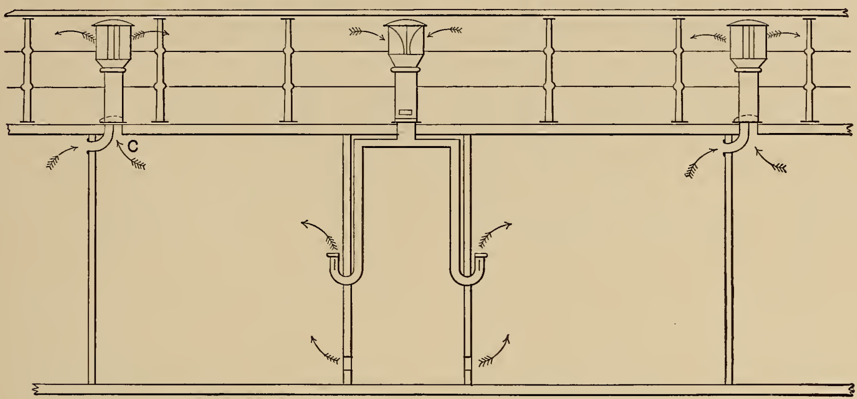
A modification of the system, which is found useful in the fruit trade, is to cover in with a movable plate the space occupied by two vertical bulkhead stiffeners. The space thus covered forms a vertical shaft. Suitable openings are made in the covering plate at intervals, and if in each hold against the forward and aft bulkhead such a shaft be made, and one be connected to the exhaust fan and the other to a ventilator, a good circulation of air can be insured horizontally through the intervening cargo. In the event of cargo of great density requiring ventilation, this can be effected by connecting the downcast shaft with a blowing fan, whilst the upcast is coupled to the suction fan; in this way the greater difference of pressure obtained will ensure effective results.

Air trunks can be formed between two frames of a ship, and horizontal thwart-ship air trunks can be formed by utilising a deck beam as one side of an air trunk, thus avoiding trespassing on cargo space.

A longitudinal section is given on page 287 of an oil boat, showing the machinery, engines, and boiler right aft, divided by a water caisson from the oil tanks. Two of these are shown full o

oil and three partially empty, and one has just been emptied and is being ventilated by the suction fan, which is shown amidships.

The two tanks forward of this are shown, one with grain in bulk resting in bags, the other with chests of tea, with bags of coffee above. Forward of this is the other water caisson.



LONGITUDINAL SECTION ILLUSTRATING THE BOYLE SYSTEM OF VENTILATION

Arrangements of the kind described have been fitted to over thirty vessels, none of which have yet met with any mishap. The cost of such a system is very small, being less than one per cent. of the cost of the ship, and as proper ventilation is considered when insurance premiums are decided upon, owners would certainly find it a matter of self-interest to give the subject careful attention. Inasmuch as valuable cargo, moreover, can be carried without tainting when ventilation is properly carried out, there is further advantage, measurable in terms of the amount received for freight.

The system described may be supplemented by a small fan to blow air into the engine-room, as is done by one of the leading mail lines, the superintending engineer having fitted branch pipes for the fan engine to deliver air to all the parts where engineers have to stand on watch.

Hitherto only the principles involved, and the methods adopted, in ventilating a special class of vessel, namely, bulk oil boats, have been dealt with; but as it has been shown that such vessels, when fitted with ordinary hatches and winches and good ventilation, are well adapted for carrying ordinary cargoes, it may be inferred that a system like that considered, with slight modifications, would serve well in other classes of vessels. The main points are to provide inlets as well as outlets, and to have the whole system under direct and absolute control,—not that unreliable control which is obtained by a slide in a ventilator shaft, when the source of motion in the air is either wind or ship velocity, or difference of temperature in and outside of the ship, but that direct and absolute control which is obtained by the stop valve on the steam pipe of a fan engine.

The ventilation of cattle boats can be very efficiently conducted on this system, and much yet remains to be done in this direction, so that in hot, close weather the cattle in the 'tween decks may have enough air, and in gales of wind not too much, or none, as the case may be.

A system which has been found to give good results, as far as cattle spaces are concerned, is to place beneath each cattle hatch a propeller fan of large diameter, coupled direct to a high-speed engine, and to cause a large volume of air to pass bodily down one hatch, along the cattle deck and up the next hatch.

The adoption of this simple arrangement has resulted in the saving of the lives of a large number of cattle.

In regard to passenger-ship ventilation, now fairly well attended to in some ocean liners, but neglected in others, there can be no question that the want of ventilation has a good deal to do with sea-sickness with many persons who are just able to endure the motion, but who succumb to the combined influence of the motion and the atmosphere of the cabins and state-rooms. Some people even prefer sleepless nights on deck to endeavouring to sleep in the vitiated atmosphere below in bad weather when the ports are closed and the hatches and saloon doors also.

In addition to the fan system various other ventilating methods have been applied, with excellent results, to large numbers of vessels, among them the system of Messrs. Robert Boyle & Son, Ltd., of London and Glasgow, which provides for special forms of so-called "air-pump" ventilators, made upcast and downcast. These are arranged in such a way that the sea water cannot readily get below: indeed, it is claimed for them that they can remain open during the stormiest weather. The principle on which the upcast ventilators act is that of induction, whilst in the case of the downcast ventilators, the air, blowing across fixed blades, is diverted downwards.

One very important advantage claimed for this system is that not only are there no moving parts, but there are also no cowls to be shifted to face the wind, a point which is much appreciated by firemen, who, in vessels not so fitted, have to come on deck and shift the cowls with any change in direction of the wind.

A system of ventilation by compressed air, delivering minute jets wherever required, is adopted in a number of Atlantic steamers, and works efficiently, so far as the passenger departments are concerned. Controlling arrangements are provided by which each passenger can regulate his own supply of air, but in this case the upcast shaft consists of any deck openings or passages, although in some ships there are also fitted air shafts, provided with electric or steam-driven fans for exhausting the foul air.

Some ships, again, are fitted with an exhaust ventilating system of pipes leading to the funnel casing. The ventilation here is obviously liable to vary in exact accordance with the condition of the fires, and is, therefore, not so dependable as when mechanical power is provided in the shape of steam fans, electric fans, or jets of air compressed by steam-driven air pumps. But in all cases some system of ventilation is absolutely necessary, not only in calm weather, but also in heavy weather when ports and other openings must of necessity be closed. This fact is happily, meeting with wider appreciation every year.

STEAM LAUNDRY MACHINERY

By Sidney Tebbutt

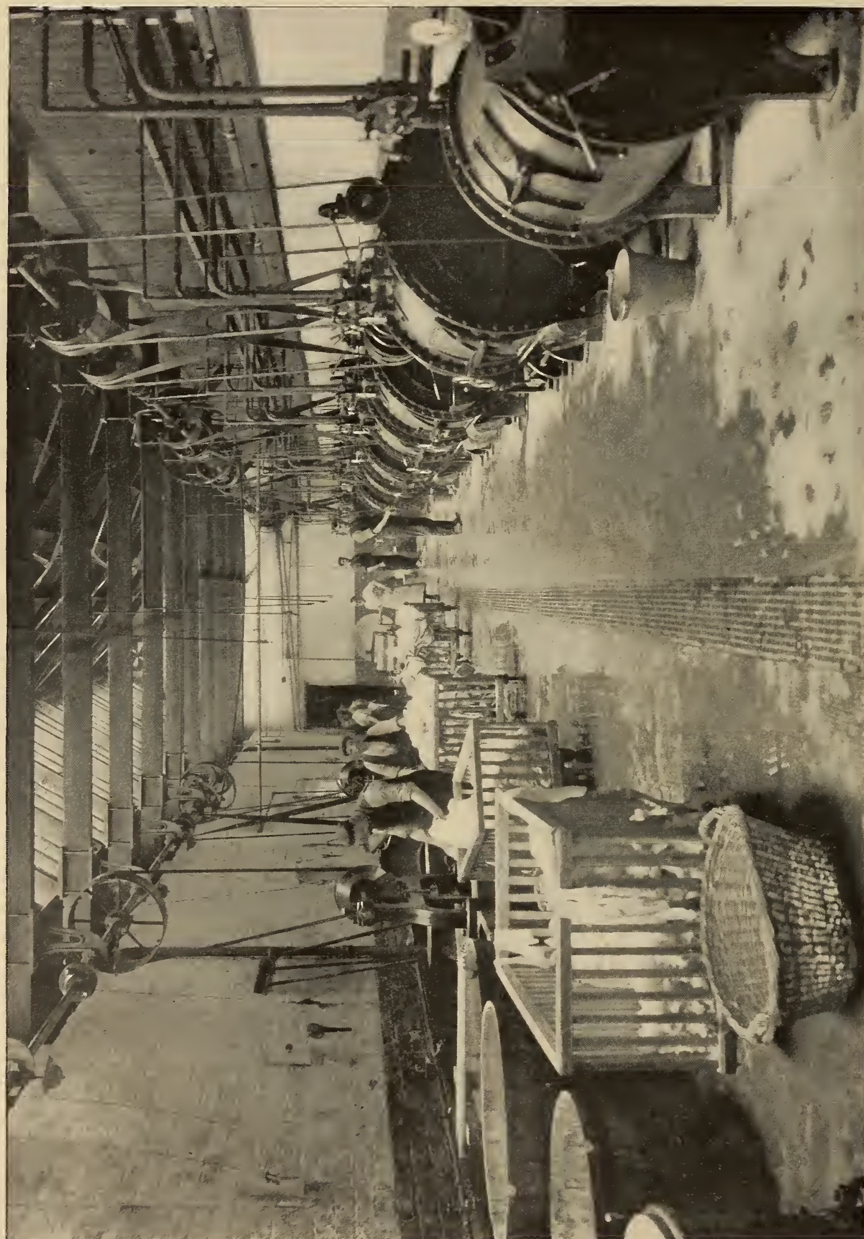
THERE is comparatively so little published information available concerning steam laundry machinery, even in catalogues of makers of such machinery, that a paper on the subject, recently read before the Institution of Mechanical Engineers of Great Britain by Mr. Sidney Tebbutt, possesses special interest, and accordingly has been reprinted practically in full in the following pages. To Mr. Tebbutt's data and diagrams, however, have been added photographic reproductions of some of the various kinds of washing and ironing machines, drying apparatus, and other laundry appliances as made by several prominent makers of Great Britain as well as the United States. These, in a great measure, tell their own stories, and help to illustrate very effectively the extent to which machinery has entered into even this homely field of work.—The Editor.

Up till only a few years ago, with one or two well-known exceptions, no engineers undertook such work as steam laundry machinery, whereas at present there are a considerable number who pay special attention to it, and some who do hardly any other class of work. The French, if not actually the pioneers, were early in the field; but it is almost entirely from the United States that the present style of machines has come.

Articles received at laundries for cleaning are of the greatest diversity as regards quality, shape, age, size, and material, and even the strongest have only slight cohesive strength. They come in all sorts of condition; some hardly require cleaning at all, while others are so soiled that it would appear to be almost impossible to get them clean. Further, the same articles come over and over again for repeated cleaning. Hence, machinery for treating them must be constructed with the utmost care to provide against wear and tear of the articles themselves. Also it must be able to stand constantly changing conditions of wet and dry, and of heat and cold. It must further be extremely simple, because the persons employed in using it are mostly girls, often young and untrained. For these reasons it is obvious that it should be of first-class and suitable material, and be well constructed. Provision should also be made for speedy repairs or renewals, inasmuch as long stoppages cannot be arranged for.

A well-arranged laundry will generally consist of two long sheds or bays, running side by side and separated by a partition. At the entrance there is a space for hampers, and then comes the sorting room, followed by the washhouse, the store-room, and the drying room, which together occupy one bay to the far end. Returning along the other side of the partition, at the far end comes the ironing or finishing room, then the airing room, and lastly the packing room, which adjoins the entrance. The office comes between the sorting and packing rooms. Goods thus arrive and leave at the same place; and in the entrance passage the packed hampers can be stored in readiness to be taken away by the vans.

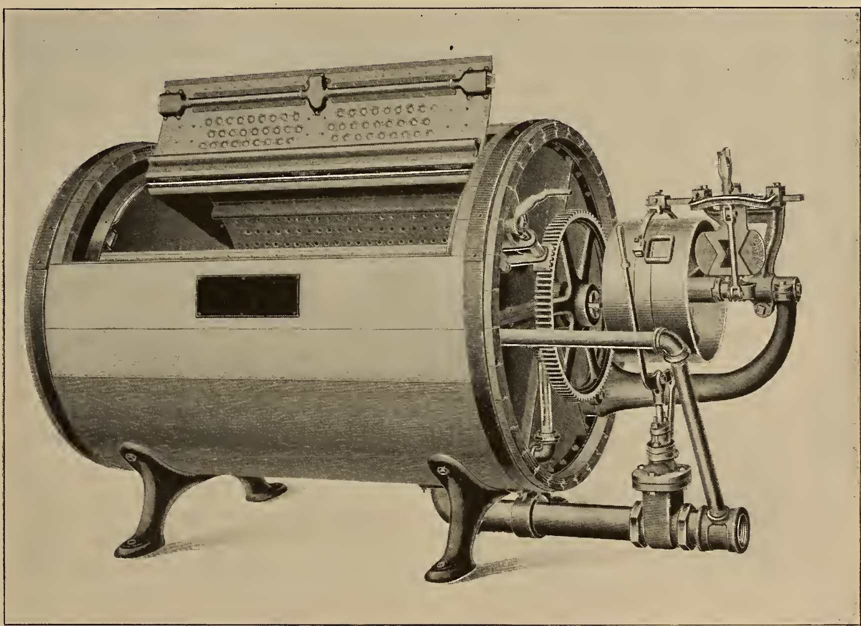
Laundry machinery can be broadly



THE WASHER ROOM OF A LAUNDRY EQUIPPED BY MESSRS. SUMMERSCALES & SONS, LTD., KEIGHLEY, ENGLAND

divided into that which cleanses and that which finishes. Commencing with the cleansing, it is to be noted that all heating of washing liquors is done by turning steam into them direct. On this account the steam must be clean, and free from grease and other impurities, or else the latter will get into the clothes. The large quantity of steam required necessitates relatively large boiler power. Inasmuch as a boiler and consequently an attendant are necessary, it will be understood that an ordinary steam engine is the most economical motor for furnishing the power required. The power needed is small; a 9-inch cylinder engine of ordinary make, running at 60 revolutions a minute, is sufficient for all except the largest laundries. If exhaust-steam injection is employed for feeding the boiler, care must be taken to avoid the introduction of grease, by the use of a minimum quantity for lubrication, and by freeing the exhaust steam from the lubricating material before it reaches the exhaust injector. Where so much heat is needed n working all the year round, it appears advisable to utilise the exhaust steam not for warming the building in cold weather, but rather for some constant requirement in all seasons.

Whatever water-softening apparatus is used must be of the utmost simplicity; it may require fairly constant attention, so long as the attention is of a simple nature. Except in particular instances, all laundries should have a water-softening apparatus. Quite apart from the other advantages that are obtained from the use of soft water, the actual saving in washing materials is considerable.



A BRASS CYLINDER WASHER, MADE BY THE TROY LAUNDRY MACHINERY CO., LTD., TROY, N. Y.

Whether for steam or water, the piping and fittings commonly used are seldom found to be tight, or right in other respects; and loss is constantly taking place, which is not readily noticed, but is continuous. It is highly important that piping should be so arranged that it can be got at with ease, and without undue disturbance of the working of the laundry. The water pipes are liable to fur up, and the steam connections or fittings to wear leaky; both, therefore, may require work to be done on them for keeping them in order.

A SET OF IRONING MACHINES, MADE BY MESSRS. W. SUMMERSCALES & SONS, LTD.

The water pipes are seldom large enough. A washing machine such as is in common use should be supplied by a water pipe of not less than 1¼ in. bore. Such pipes should be of copper, and should have unions at all branch points for taking apart to clean; the position of the unions is important. As there is only at most a few feet head of water pressure, the copper pipes can be thin; and if in the long lengths plenty of unions are put in, thin piping can be easily handled without injury. A thickness of No. 19 to 20 B.W.G. or 0.040 to 0.036 in. will do perfectly well for copper water pipes. Where thick pipes are used, or such as are cut with circular cutters in fitting them up, all ends should have their burrs filed off after cutting.

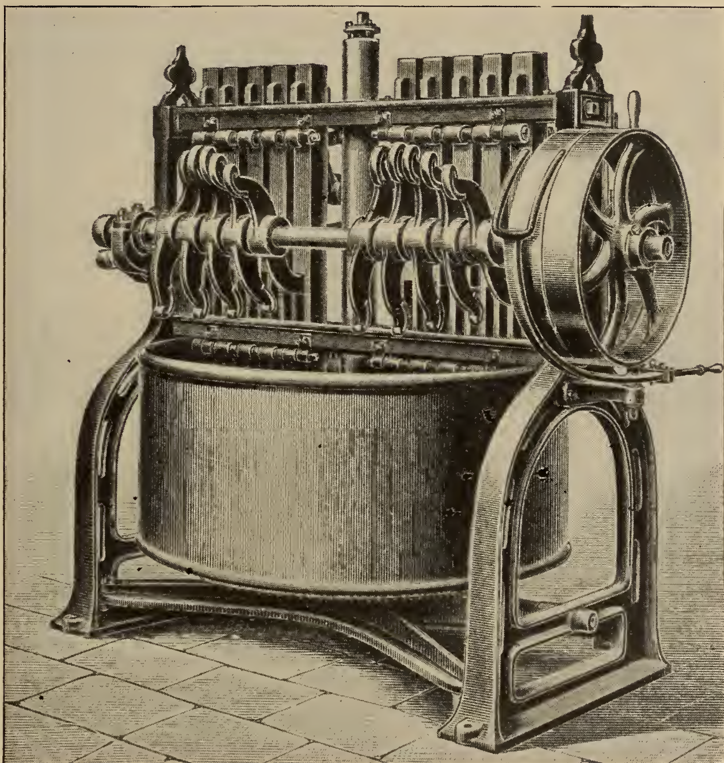
Another important matter is the construction of the bends and tees, and of the taps and cocks which are usually made with too small waterways. If these are supplied by an ordinary coppersmith, it will probably be found that 1¼ in. piping will not deliver more than a 1-inch pipe running full bore, and often much less. Especially is this the case in regard to cocks or valves. A good plan is to have all these fittings of a size larger than is large enough to put on the outside of the ends of the pipe, and then the waterway will be found to be about right. No threading will in this case be used, the joints being soldered.

The steam pipes can be made of ordinary wrought-iron steam piping, or of galvanised iron of the kind used for water, unless a high pressure is used, which is not advisable; 60 to 70 pounds per square inch is quite high enough. It is not advisable to have less than ½ in. steam piping anywhere, and a ½-in. pipe into each end of the washing machine, leading out of a ¾-in. pipe, will be sufficient. The valves have such constant wear that re-grinding and renewal are required at frequent intervals; and, therefore, the piping should be so arranged as to be easily got at, and the junctions of the main pipes should be

well made with brass unions ground in. The whole of the piping should be carefully designed and the fittings well chosen, because these play a highly important part in steam laundries, and it must be remembered that they are not used with care. Few parts fail more than the piping. Under certain conditions armoured hose piping has been successfully adopted. Lever throughway valves for water may be used in some cases; but if screw-down valves are adopted, the valves themselves should be of leather.

Where a fan is properly arranged for carrying off steam, wood pulleys can be used without any injury to themselves from dampness, and without any difficulty in belts obtaining proper grip for driving the machines.

A usual method of washing is first to soak the linen for as long as possible, up to 24 hours, in soft water having a little soda in it, at a temperature of about 70 deg. F. Then wash with soap and soda solution for 20 to 30 minutes in soft water warmed to about 100 deg. After letting this liquor run away for, say, five minutes, wash a second time in a fresh soap and soda solution, the same as the first, only somewhat hotter, raising it up to, say, 130 deg. before finishing with it. A third, similar liquor is used for boiling. It is important that just enough soap and soda should be used to keep a good lather during these operations, but not too much, for if it be "frothy" the subsequent washing is not so well effected. A run of 20 minutes is sufficient after the boiling point has been attained. After this, rinse in two or more lots of water, to

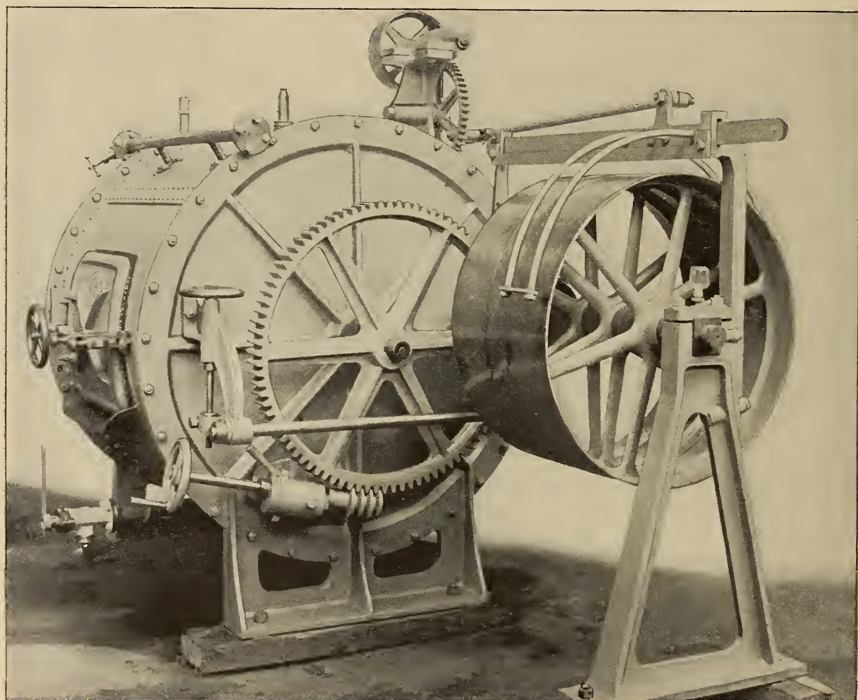


THE ORIGINAL TYPE OF STEAM WASHING MACHINE, MACALPINE'S PATENT, MADE BY MESSRS. MANLOVE, ALLIOTT & CO., LTD., NOTTINGHAM, ENGLAND

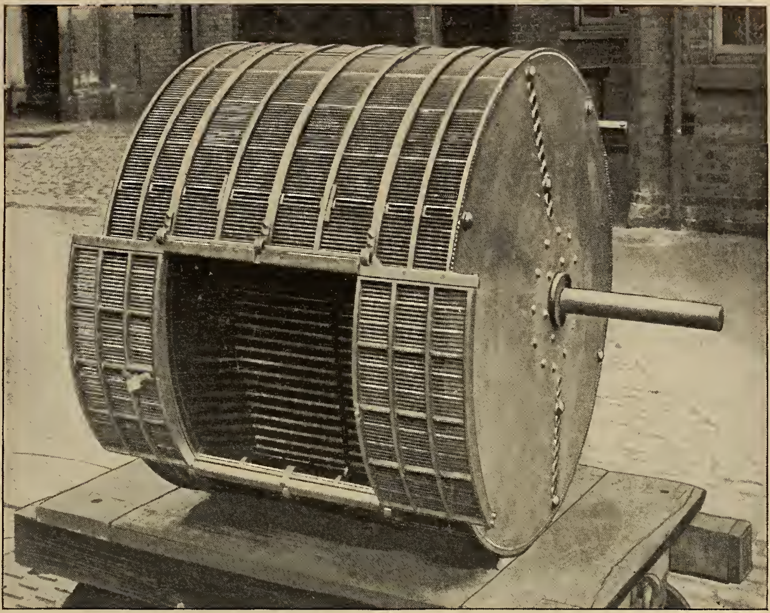
the last of which the necessary blue colouring is added.

This process can obviously be modified greatly in many ways and under varying conditions. Soaking may be done in separate appliances, as may also rinsing and blueing. Some goods do not require a second wash, while others need two short washes only. If soaking is done in the washing machine, only 10 minutes should be allowed for it, and the soaking liquor may be used for the first washing. If all the operations are done in one machine, from 2½ to 3 hours will be required for linen that is ordinarily soiled. There are also other methods of washing, though not commonly used.

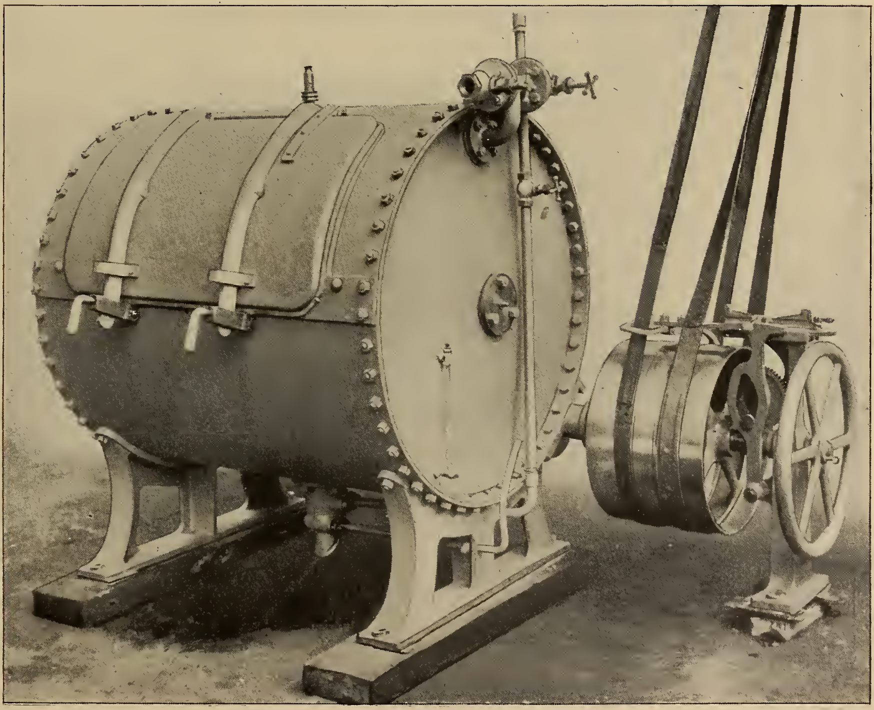
The kind of washing machines required depends largely upon which of the three plans of cleansing that are in general use is adopted. The first plan is to use two washing machines for the actual process of washing alone, leaving the soaking, boiling, rinsing and blueing to be done by separate appliances. The second is to perform in a single machine all the processes of chemically acting on the dirt and clearing it away. The third plan is the same as the second, except that the boiling, which in the first and second plans is done at atmospheric pressure, is done in the third under steam pressure up to 10 pounds per square inch, or 239 deg. F. For the first process, washing machines with their main parts constructed of wood may be advantageously used, because satisfactory machines for this process can be constructed of wood at a low cost, inasmuch as the heat required for the washing proper, say, up to 130 deg. F., does not seriously injure some kinds of wood. For the second process the machines should be made entirely of metal, because the boiling acts rapidly on nearly all sorts of wood, and soon pulps it. In some of these machines both wood and metal are employed in combination; but ex-



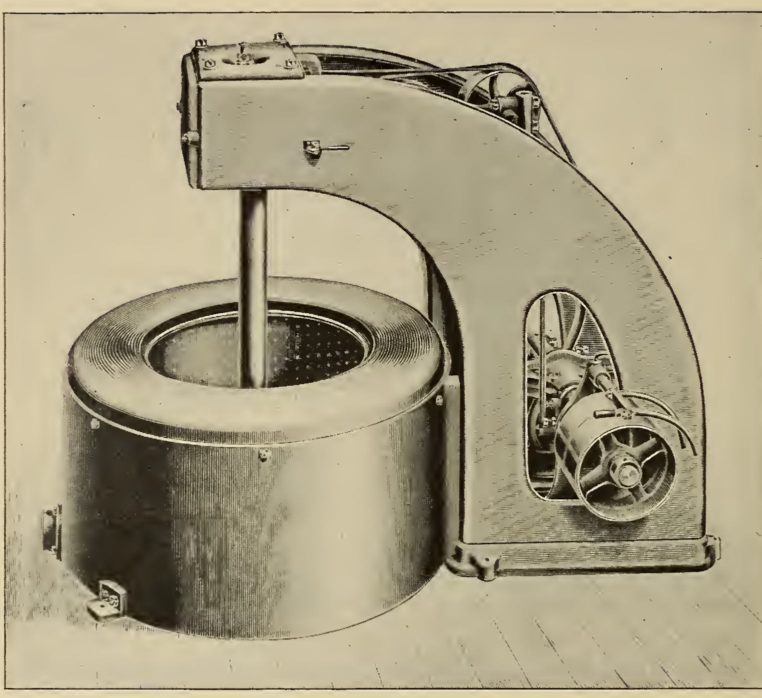
A ROTARY WASHER, MADE BY MESSRS. MANLOVE, ALLIOTT & CO., LTD.



THE REVOLVING CAGE OF A WASHER

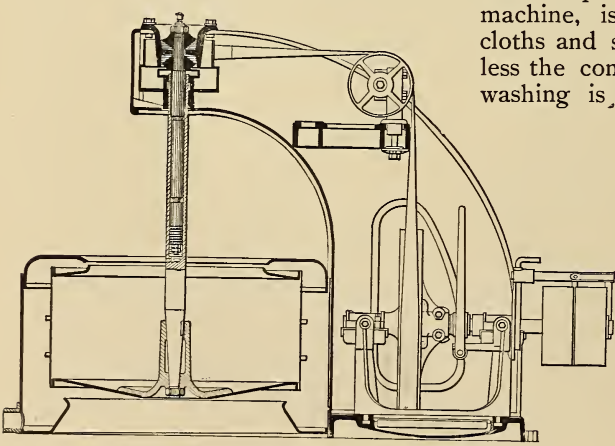


ANOTHER FORM OF ROTARY WASHER, MADE BY MESSRS. MANLOVE, ALLIOTT & CO., LTD.



A HYDRO-EXTRACTOR, MADE BY MESSRS. WATSON, LAIDLAW & CO., GLASGOW

cept for cheapness there is no apparent advantage in combining the two materials, and the renewing of the wood is always a trouble. The third process demands still more urgently that the whole of the machine should be made of metal; and to hold steam at a pressure necessitates also an entirely different design of machine, which is much more expensive.



SECTIONAL VIEW OF A HYDRO-EXTRACTOR

Washing machines are, perhaps, the most important of all the appliances in a steam laundry; there is a large variety, of which those only that represent the standard makes need be considered. The method of washing by letting beaters act upon the fabric, as in the dolly machine, is useless, except for tent cloths and similar heavy material, unless the condition of the material after washing is a matter of indifference. There are also machines which act by continually squeezing small masses of clothes, and this mode of action may be useful under certain conditions.

But 90 per cent. of the washing machines in use act by continually lifting the clothes a certain height out of the water, and then allowing them to fall into it again. Obviously a strong wash-

ing action can be obtained by having a sufficient fall, and the action in any one machine can easily be regulated within limits by filling it with more or less water, and thus altering the height of the fall. This commonest form of machine, illustrated in Fig. 1, has an outer cylindrical casing fastened to circular discs for its ends; and inside the casing, which is stationary, revolves another cylinder or cage, in which the clothes are placed.

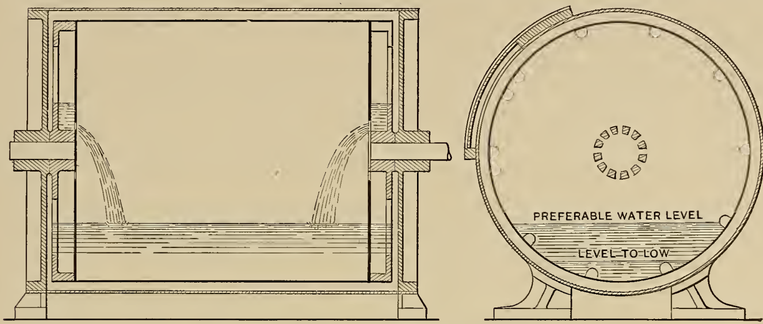


FIG. 1.—THE COMMONEST FORM OF WASHING MACHINE

AN ORDINARY TYPE OF DRAW-HORSE DRYING CLOSET, MADE BY MESSRS. MANLOVE, ALLIOTT & CO., LTD.

Between the insides of the two cylinders there is communication for liquids through holes made in the metal or wood forming the inner revolving cylinder.

The direction of revolution of the latter is continually reversed. The reversing action is usually obtained by two belts, and the number of revolutions each way varies from three to five, according to the maker's experience. This kind of machine came from America, and the revolving cage is usually made about 3 feet diameter. The striking gear, which is mostly copied from the American original, is in some instances ingenious. A machine which has had a fair amount of success is illustrated in Fig. 2, giving a longitudinal or end motion to the contents in turning them over; but its action is too

A SET OF DRYING CLOSETS, MADE BY MESSRS. W. SUMMERSCALES & SONS, LTD.

mild, although it does well for flannel washing.

It is most important to provide against any possible iron-moulding or rust. Where the machine is of wood this is a difficulty, because iron bolts seem impossible to keep in order, and brass bolts are not at all satisfactory. The best plan is to fasten the wood together with brass wood-screws. Experience seems to show that, where galvanised iron comes in contact with wood in the presence of water, sooner or later the oxidation will eat through the zinc. The use of brass wood-screws also enables all internal projections to be easily avoided, which otherwise in some instances is no easy matter. Indeed, most machines are faulty as regards the interior surface of the revolving cage, often owing to the lifter fastenings or the door fastenings. The door is a prolific source of trouble. If the fabric that is being washed can manage to squeeze itself into any space between the door and the body of the cage, cuts will at once be made in the fabric when the cage is of metal. Sliding doors generally avoid this danger entirely. Teak is probably the best wood for cages. In order to avoid wear to the

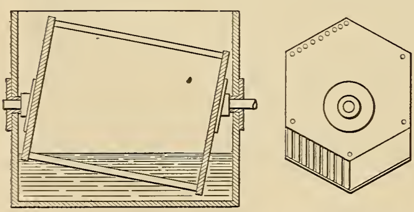


FIG. 2.—A HEXAGONAL CAGE ON OBLIQUE AXIS

clothes in metal cages, a plan of countersinking the holes in the cage by bending the sheet metal outwards at the holes has been adopted in America. Where the holes are situated so that the clothes will rub against them, the plan is commendable.

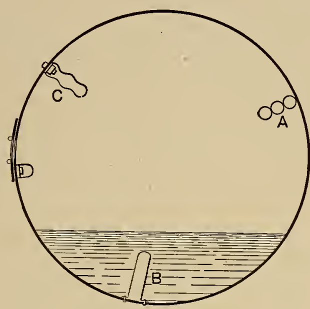


FIG. 3.—LIFTERS

For gripping the clothes and helping to lift them, pieces of wood or metal are fixed longitudinally along the inside of the cage, as shown in Fig. 1. Wood lifters are sometimes preferred; but except that it gives, perhaps, a better grip, there is no apparent reason for using this material, and brass never wears out. The American machines are behindhand in the matter of the best form of lifters, and seem to indicate a failure to realise what is required. The effect of the lifters, such as are used in the American machines, and largely adopted in the English, is to roll the clothes round; and the reversing motion of the cage is powerless to prevent this from taking place to such a degree that in some laundries the clothes become a tangled

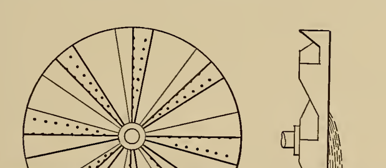


FIG. 5 —CIRCULATING ACTION

mass, which has to be lifted bodily out of the machine and to be separated by hand, or if not so bad as this, yet requiring the utmost care to unravel. Even it they have not been torn in the machine, tearing can hardly be avoided in the unraveling.

A cage can be constructed, and is in use, which so little "ropes" (as this matting together is called) that the clothes come apart with the utmost ease; this result is accomplished by employing a judicious form of internal projections or real lifters, and right numbers of them, properly arranged. In Fig. 3 are shown several plans of such lifters, which do not act as rubbers. Lifter *A* is made of brass tubes, which, however, are difficult to fasten securely at the ends, and are liable to let clothes get between them and to cause injury to the fabric. Lifter *B* presents the objection of projecting rivets and edges, against which the clothes become injured; also the holes for the water can-

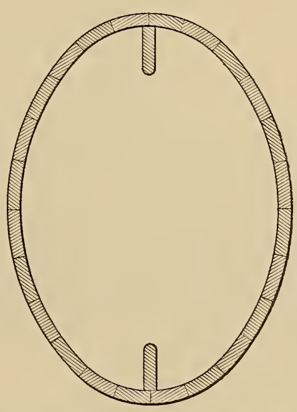


FIG. 4 —A SINGLE-CAGE WASHER

not here be made close to the corners of the lifters, where they should be. Lifter *C* fulfills all conditions required, the bolt heads and edges being all kept inside it. If made with open ends, these lifters can be used for carrying water up and letting it run out upon the clothes lifted; but this is hardly worth doing, and is also inadvisable otherwise.

Fig. 4 shows a washing machine having only a single cage, which is watertight, and into which the washing liquid and clothes are placed. This single-cage form of rotary machine has nearly gone out, except for hand machines.

The particular section here shown has been used in Germany for many years by the inventor, and is interesting as showing that lifters are no new idea.

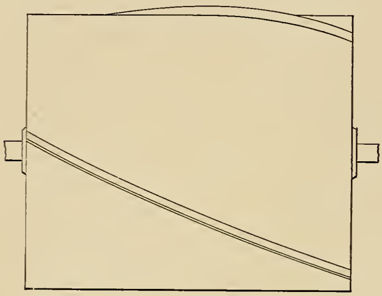
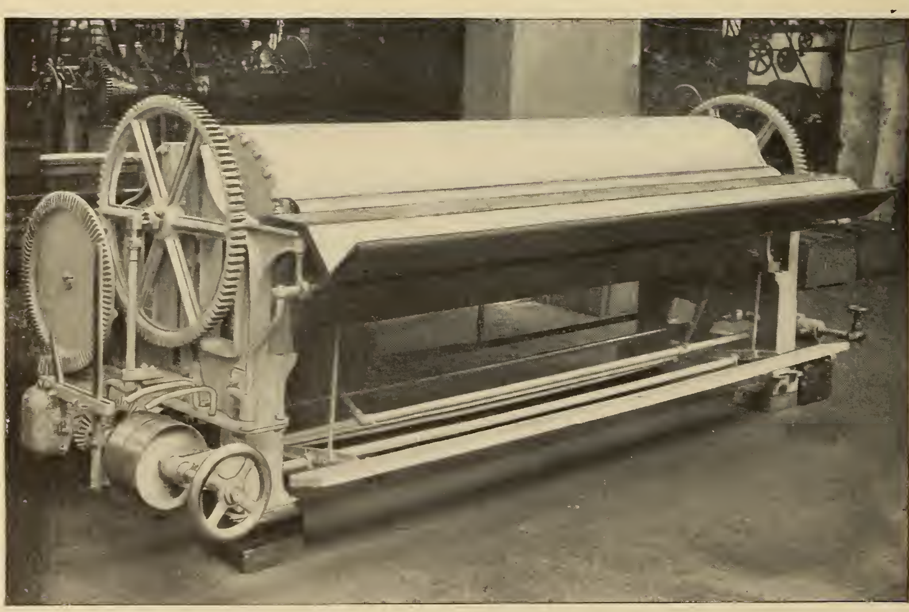


FIG. 6.—A CIRCULATING ARRANGEMENT

The greater the speed, the higher the clothes will be lifted before falling, unless they be carried right round or beyond the top centre; but the author believes they undergo more wear and tear at the higher speed, although he hardly knows why. Some machines are run at 30 revolutions per minute; but this he considers much too fast; 25 should be an outside speed, and to some users 20 would appear to be fast enough. The object is to give the greatest practicable height of fall to the clothes. If only a small depth of water is used, the clothes fall largely upon the sides of the cage, which, moving rapidly, are sure to cause wear and tear. The clothes should fall into the water clear of the cage.

A sufficiently full fall may be taken to be when the clothes drop from the cage at about 30 deg. above the horizontal axis, or 60 deg. before reaching the zenith, so that the forward motion shall not carry them beyond the centre of the cage during their fall. But as no machine has been constructed in which the whole internal action can be observed in working, the details of what actually takes place inside the cage are not yet clearly ascertained. The amount of clothes which can be treated at one charge in a revolving cage of, say, 3 feet internal diameter and 3½ feet long, is considerable; measuring by a common laundry standard, 250 shirts can be satisfactorily treated at a charge, weighing about 180 pounds when dry, and 250 pounds after centrifugal drying.

The supply of steam and water and liquor should be introduced into both ends of the machine at the same time;



AN IRONING MACHINE, MADE BY MESSRS MANLOVE, ALLIOTT & CO., LTD.

and the soap and soda, which should always be kept in solution, should be added while the machine is in motion, through an arrangement specially constructed for this purpose. Endeavours have, of late years, been made to add some arrangement for producing a circulation of the washing liquor while the machine is working, so that it may be continually passing from the outer casing into the revolving cage, and round again into the outer casing. Some of the plans are ingenious and valuable. Two are illustrated in Fig. 1 and in Fig. 5. That shown in Fig. 1 is constructively good; it delivers the water into the cage in the centre of the ends, and does not need to force it into the cage against the water and clothes; whereas, on the plan shown in Fig. 5, the water has largely to be forced into the cylinder.

Although machines will do good work without such an arrangement of central delivery, it is a distinctive advantage, and should be adopted, unless some disadvantage is found to arise from its use. One disadvantage likely to be met with is the difficulty of cleaning the machine; this is an important matter, which should always be kept in view when designing a machine. For this reason, and also for ease of putting the clothes in and taking them out, the door of the revolving cage, as well as that of the outer casing, should be the full length of the machine where possible. There should be fitted to each machine a gauge-glass, which, in the absence of steam pressure, need not have its upper end closed In Fig. 6 is shown a plan that has been adopted for circulating the water which lies at the bottom of the casing of a washing machine. Strips of angle-iron, about 1 in. by 1 in., are here riveted helically upon the outside of the revolving cage; these act like a quick screw or rifling. They also help to stiffen the cage, and enable thinner sheet-metal to be used for it.

A SHIRT SLEEVE IRONER, MADE BY THE AMERICAN LAUNDRY MACHINERY CO., NEW YORK

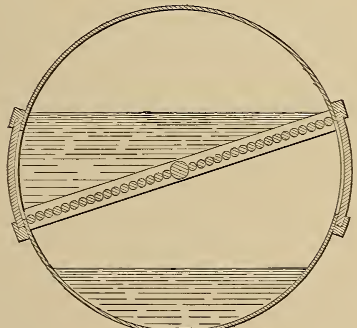
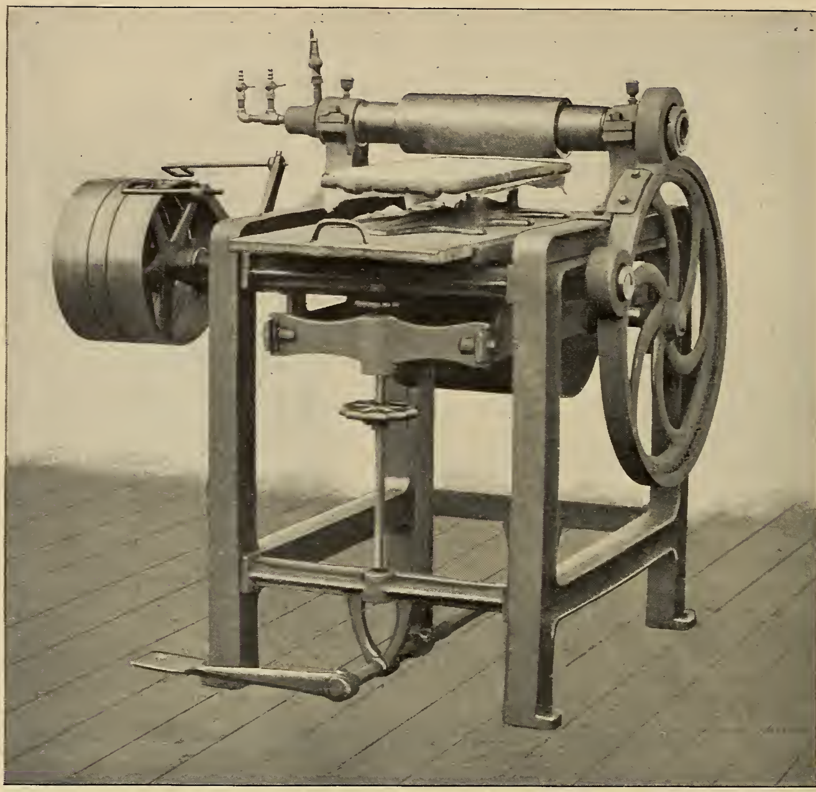


FIG. 7.—A CAGE WITH TWO COMPARTMENTS AND TWO DOORS

Most of the foregoing remarks apply equally to machines that work with steam pressure, which, however, is used only in the process of boiling; but in these it should be noted that the door cannot be made large, and that in nearly all respects the design will be different from that adopted where no steam pres-



A COMBINED SHIRT BOSOM AND COLLAR AND CUFF IRONER, MADE BY THE WILSON LAUNDRY MACHINERY CO., COLUMBIA, PA.

sure is used. As a rule, machines which work under pressure are made with a cage of larger diameter, although shorter in length; and they often have a central longitudinal partition throughout the length of the cage, dividing it into two semi-circles, as shown in Fig. 7. This plan has the advantage that the axle can here be formed by a shaft running right through from end to end, which is constructively good, especially where the cage is of considerable weight. It has the disadvantage, however, of requiring two doors in the cage, one for each compartment.

In all respects machines working with steam pressure are much more expensive, and also more difficult to clean, and the attendants should be men, which need not be the case in the use of machines working without steam pressure. The advantages claimed for the employment of steam pressure are that the machines wash better, produce a better colour on the clothes, and also thoroughly disinfect the articles washed. These are important points, and, if realised in practice, should lead to the adoption of steam pressure in nearly all instances, certainly where the necessary capital and space are available, in spite of the fact that the steam-pressure machines may be rather more costly to handle. As regards their better washing powers, it is difficult to speak with any certainty. Some users are decidedly in their favour; others maintain that equally good results are obtained without the steam pressure, and with consequent freedom from the injurious pulping action which, they allege, is caused by its use, notwithstanding that the pressure is on for only about 20 minutes for each batch of clothes. The

claim of superior washing powers appears to be problematical, the pressure being used only in boiling; and the author believes the truth is far more difficult to get at than would appear at first sight. Thousands of atmospheric washers are turning out clean work without difficulty.

The common adoption of steam pressure in washing machines for sanitary motives would appear to be due to the belief that machines which do not wash or boil under pressure are not sanitary. It is one of the claims of washing under steam pressure that it destroys all infection. Authorities on this subject are unanimous in the conclusion that boiling clothes or other articles at atmospheric pressure is an efficient sterilising process; and in the treatment of wounds, where textile fabric chemically sterilised is not at hand, there need be no fear in using what has come direct from the laundry, as it is, to all intents, completely free from infection.

There does not seem to be evidence of infection having been spread through laundries; and, consequently, in spite of the slovenly way in which many laundries do their work, it would appear that they, nevertheless, happily afford a great protection from the spread

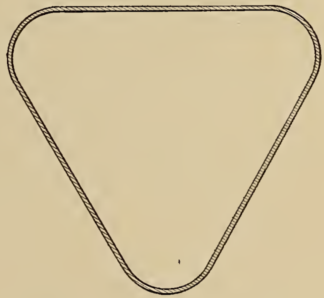


FIG. 8.—CROSS SECTION OF A GERMAN CAGE

of disease, and that where ordinary boiling is carried out there is complete protection. Flannels are never boiled, but are washed with potash soap, which is the proper material to wash them with, and is said to rank high as a disinfectant. The preference for atmospheric washing machines, or for those working under steam pressure, resolves itself into the ability to construct a machine which will successfully treat the clothes with the least appreciable wear and tear, and not be too expensive to construct or use.

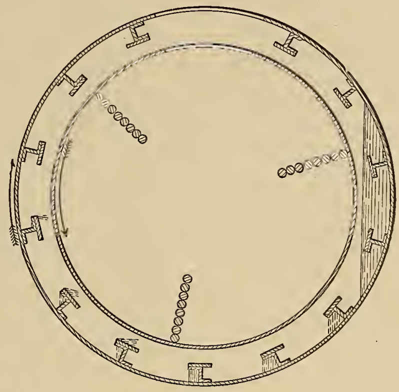


FIG. 9.—A WASHER WITH CASING REVOLVING OPPOSITE TO CAGE

A common form of washing machine in Germany is shown in its general shape in Fig. 8. It is built on the same lines as ordinary rotary atmospheric machines, except that in nearly all instances the outside casing as well as the inside cage can be revolved, with the object of turning it round so that the doors shall come below when the clothes are ready for taking out. It is raised high enough on its bearings for a trolley to be run in beneath, into which the clothes are allowed to fall. Although the saving in time does not appear to warrant the necessarily increased cost and other disadvantages of this plan, most of the German laundries are wedded to it. Single machines which perform in themselves all the processes of chemically acting upon the dirt and clearing it away are open to the objection that, although the liquor is drained off between each operation of cleansing, a considerable amount is retained by the clothes, and helps to foul the next lot of liquor.

An ingenious attempt has been made to construct a machine which shall perform all the operations in itself in a

theoretically correct manner, and yet without any handling of the goods. For this purpose the outer casing of an ordinary machine is made to swivel, so that between each operation it can be turned

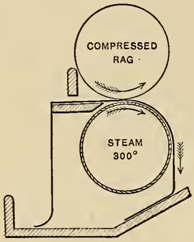


FIG. 10.—AN IRONER WITH COMPRESSED RAG ROLLER

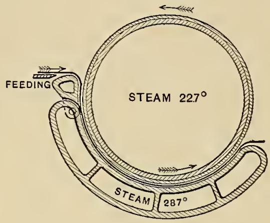


FIG. 11.—A DECOUDIN IRONER

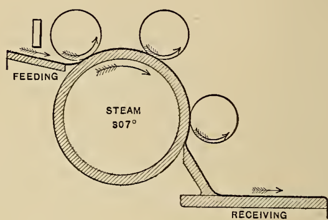
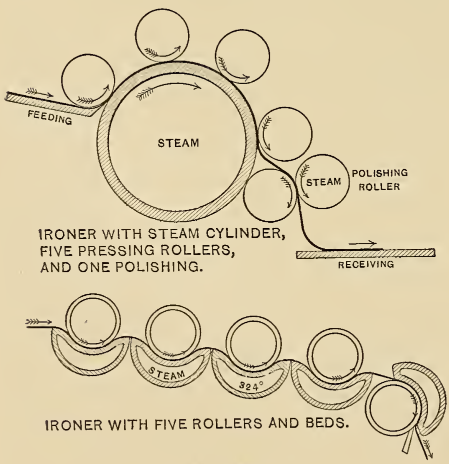


FIG. 12—IRONER WITH STEAM CYLINDER AND THREE ROLLERS

with its axis vertical; the inner cage is then made to revolve rapidly, like a centrifugal machine, whereby the clothes are effectually cleared of the dirty water, none of which remains to contaminate the fresh liquor next introduced. It is not likely, however, that this machine will come much into use, owing to a variety of reasons which have nothing to do with the quality of its work.

In North Britain a machine is much

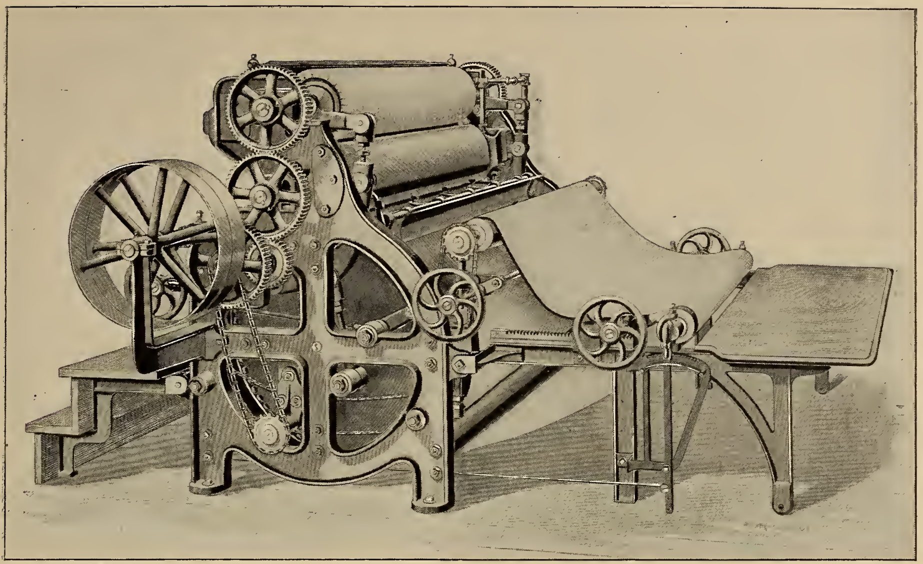


FIGS. 13 AND 14.

used, shown in Fig. 9, having an outer casing of large diameter, which revolves in the opposite direction to the inner cage. The outer casing has inside projections, which carry the water up and discharge it continuously upon the brass bars that form the circumference of the inner cage. The inner cage has large lifters, which raise the clothes for their fall. There is also an elaborate arrangement for discharging jets of steam upon the clothes, and the machines can be worked under steam pressure. It is obviously an expensive machine to make, and complicated; and it has one fault common to all complicated machines, namely, that it is difficult to keep clean. Moreover, it cannot wisely be made small enough to take only a small quantity of work, because its cost relatively to the output would then be prohibitive. Washing machines in general deal with such a large quantity of work at each charge that only where large quantities of the same class of work need treating at one time can full charges be obtained; and then, in case of any error in the process of washing, the quantity of clothes treated is so great that it becomes a serious matter to correct the defect. For the finer classes of goods also it is questionable whether large machines do not have an injurious action.

Many other devices have been tried for washing clothes, and some are still in use. Other ingenious plans may be of value for special requirements, such as hand-power. But the advantages of the few that have been described outweigh altogether those of all the rest.

The first stage of drying is effected by a centrifugal extractor, of which any of the usual forms are suitable. The second or final stage of drying is performed by a drying-room. The method



AN IRONING MACHINE FOR LARGE WORK, MADE BY THE AMERICAN LAUNDRY MACHINERY COMPANY

of heating and arranging and working this room is important, and great improvements have, of late, been introduced. It is a subject too large to be treated here, inasmuch as no one method of heating the air for the drying-room, or of causing it to act upon the clothes, has become at all general. The tendency is to adopt a plan of blowing air into the room by means of a blower, which forces it previously through an exhaust-steam heater. Some articles are not dried at all in a drying-room, but are ironed at once, when taken direct from the centrifugal machine.

Ironing machines, in the many various forms in which they are at present made, constitute what may be termed finishing machines. They all act mainly in the same way, although they differ greatly in design and capacity. In nearly all there is a hard, polished surface of metal, which is heated by steam, or gas, or electricity; and a second hard surface of metal or wood, which is padded over with layers of felt, covered with a wrapping of cotton sheeting. The padded surface holds the article which is being ironed, so that it can be made to rub against the polished heated surface, while allowing for irregularities of thickness in the article itself.

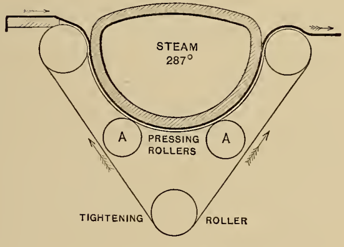


FIG. 15.—IRONER WITH ENDLESS FELT BAND UNDER STEAM BED

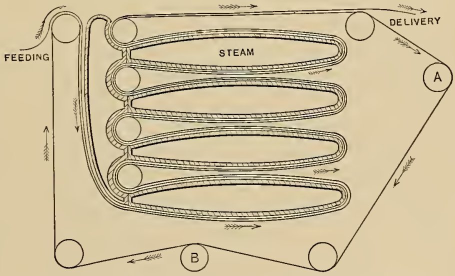


FIG. 16.—IRONER WITH FIVE STEAM CHESTS AND COTTON DUCK BAND

The first machine to be mentioned,

and the only one of its kind, has no padded surface, but has two hard rollers, as shown in Fig. 10, of which one is a hollow cylinder, generally of brass, heated by steam inside; the other roller is made of compressed layers of rag, cemented together under hydraulic pressure, and afterwards turned up true in a lathe. A roller of this substance, although expensive to make, acts with much less injurious effect on the linen than would two metal rollers, and yet has great hardness and durability. Linen, if constantly treated afterwards by the same machinery that is used in finishing it when new, would soon wear out; this rag-made calendar, however, acts in a most innocent way. It is, nevertheless, suitable for only one class of article, namely, table linen which requires starching; this it finishes in a superior style. The steam pressure in the heated roller should be not less than 50 pounds per square inch, the corresponding temperature being 298 deg. F., and the drying is slow, requiring the articles to pass through at least three times in order to finish them, when the speed is about 25 feet per minute. With these rollers it is difficult to finish the linen so that the edges are square and even.

The next division of ironing machines comprise those which finish the same class of goods as table-linen, namely, sheets, rubbers, smooth towels, and such other articles as are of uniform thickness. The usual width for these machines is 108 in. The most common form is known by the name of its French inventor, Decoudin, and has been arranged in various ways, one of which is shown in Fig. 11. It consists of a large hollow cylinder of cast metal to hold steam, generally at a low pressure of only 5 pounds per square inch, or 227 deg. F.; and of a hollow concave casting or chest, shaped to fit the cylinder, having its surface polished and accurately finished where it touches the cylinder, and made to stand a steam pressure of at least 40 pounds per square inch, or 287 deg. F. The cylinder is padded with several thicknesses of superior woollen felting, and revolves with a surface speed of at least 15 feet per minute. The chest is made to encircle the cylinder for as much as about three-eighths of its circumference. Sometimes the chest is above the cylinder, but far more often it forms a bed below.

In some of these machines an arrangement is made to give the chest a transverse reciprocating motion if desired, parallel to the axis of the cylinder, so as to put a high finish on the goods in ironing them; but this has now been almost entirely given up. The action of drying is twofold. A wet article, fed into the space between the cylinder and the bed, becomes heated; and by the time it emerges from the other side, most of its moisture has been driven into the padding of the cylinder, and a good deal of the remainder passes off in the form of steam while the article is cooling. An article which has come direct from the centrifugal drying machine is found to be well dried after passing through twice at a speed of about 15 feet per minute.

During the time that the padding on the revolving cylinder is exposed to the air, the wet which it has absorbed is driven off in the form of vapour by the heat it has received from the steam chest or bed, aided by the heat of the steam inside the cylinder; and by the time it comes round again to the bed, it should have become dry enough for acting on fresh wet linen. The cylinder being uniform in shape and thickness, and not subject to extreme differences of heat and cold, never gives trouble by cracking; but the bed in many instances has become cracked so as to be rendered useless. Not only is the bed of irregular shape, but it has to stand a fairly high pressure for cast metal, namely, at least 40 pounds per square inch; and it is constantly having its upper surface alone cooled rapidly by the wet linen coming against it, causing great contraction and expansion. If the ends of the bed are left open in casting, and afterwards covered over with plates bolted on to make the whole steam-tight, there is much less liability of its cracking than if the ends are cast solid. The fault of the machine, theoretically,

is that the steam generated cannot get away as fast as it is formed, but is bottled up until the wet part of the felting has passed completely clear of the bed.

To overcome this fault, machines have been made like those shown in Figs. 12 and 13, in which the central or main cylinder alone is heated, but is not padded; the rollers placed around it are all padded. The wet linen fed to the cylinder is carried round by its revolution, and pressed against its hot surface by the rollers, between which the steam can escape freely. All the rollers are pressed against the cylinder by spiral springs. Sometimes an extra roller is added on the delivery side, driven in the same direction as the cylinder so as to act as a doffer, for causing any article which sticks to the surface to be detached from it.

In the machine shown in Fig. 13 a pair of rollers, of which the outer or polishing roller is heated and not padded, receive the linen after it has left the cylinder, and press it between them so as to give more finish to the upper side, which, till then, has come into contact with the padded rollers only. A speed of about 18 feet per minute is advised; the number of times it is necessary to pass the linen through varies greatly. The fault of this class of machine, theoretically, is that the linen is pressed into close contact with the metal surface of the cylinder only along a line, instead of for some width or length of circumference. The claim is not well founded that, with the larger machines of this class, sheets will be dry after passing through once; unless the machines are in perfect order, several times of passing through may be required.

Conduction and consequent drying are far more rapid where articles are brought into close contact with the drying cylinder by pressure than where they touch it without pressure. One difficulty experienced in using these machines lies in getting all the rollers of exactly the same diameter; this arises partly from their surface becoming compressed permanently. If the first roller is too big, it passes the linen forwards too fast, and loosens it between the succeeding rollers, and thus prevents its proper contact with the cylinder. But if it is too small, it delivers the linen slower than the succeeding rollers take it, with the result of stretching and straining it. For this reason, although the machine may appear innocent of causing injury, it may really be doing constant and serious harm to the goods it is treating.

The machine shown in Fig. 14 has been designed for overcoming these difficulties, both theoretical and practical. It consists of four padded rollers, about 8 in. in diameter, not heated, which are pressed by springs against four heated beds of cast metal; the latter are so arranged as to form one continuous bed, and each is hollowed out to fit the roller for some considerable distance. By this arrangement the linen is pressed against the heated metal surface for a considerable distance, while at the same time there are spaces at intervals for the steam to escape. The rollers, here working into surfaces accurately formed to the curve of their circumference, are far more easily kept true and of the same diameter. Steam up to 80 pounds pressure, or 324 deg. F., can be used, and the speed of ironing can be varied from 12 feet to 20 feet per minute.

Sometimes an arrangement is added, as shown in Fig. 14, for finishing the upper surface of the linen, as in the preceding machine (Fig. 13); but here, instead of two rollers, there is one only, and a bed hollowed out to fit it. Linen taken direct from the centrifugal drying machine is intended to be dried by once passing through this machine; but, although the drying power is great, the intention has hardly been realised in actual working experienced with the usual run of goods. The felting used for padding the rollers is not destroyed so quickly in these machines as that covering the cylinder in the Decoudin machine, which is rapidly burnt by the heat below it, and requires renewing frequently. As the renewal involves an appreciable cost, this is a point that

IRONING MACHINES, MADE BY MESSRS. SUMMERSCALES & SONS, LTD.

requires consideration when choosing a machine.

A Decoudin ironer has been made, having the surface of the hollow cylinder perforated with many thousand holes, for the purpose of letting the steam generated pass off through them at once. It is a praiseworthy endeavour to overcome a real difficulty in a simple manner, but has not made any headway, probably because the moisture does not pass through the padding, and the extra heating power of the steam in the cylinder is lost. One of the faults of most of the machines hitherto described is that the padding on the rollers or cylinders rapidly becomes compressed by use after being put on fresh, and then the reduced diameter does not fit correctly into the bed hollowed out for the larger size when new.

pressure by means of two loose rollers, *A A*, which, not being driven independently, have no action either to stretch or loosen the linen passing under them. The lower roller can be depressed or raised so as to give the right degree of tension to the band; and to overcome the difficulty of the band contracting and narrowing in width under certain conditions, this lower roller is made with one-half having a shallow right-hand thread upon its surface and the other half a left-hand thread of such coarse pitch that the effect is to stretch the band wider.

The machine is not made to revolve quickly, because if it were, the band would probably not get dry during the time that it is not being held against the hot bed. It is run at about 12 feet per minute, and at this speed the goods

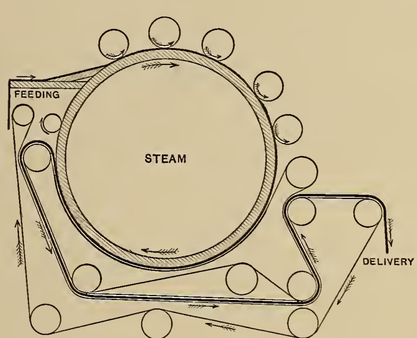


FIG. 17.—COMBINATION IROFER, WITH TWO ENDLESS BANDS

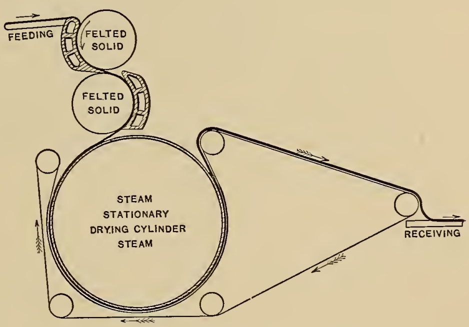
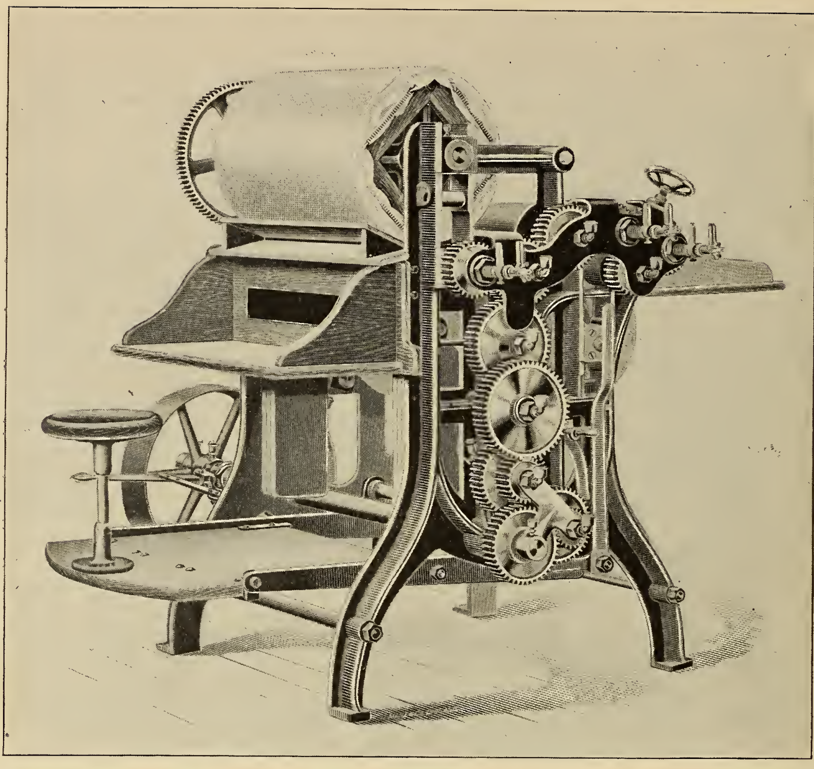


FIG. 18.—DECOUDIN IRONER COMBINED WITH LARGE DRYING CYLINDER

Of ironing machines which handle the goods by the use of endless broad bands, the simplest is illustrated in Fig. 15. It consists of an endless band of heavy felt, guided by passing over rollers, which, being made to revolve, cause it to progress, and are so arranged as to make it press against the polished convex surface of a hollow metal bed heated by steam pressure inside. The details of this machine have been well worked out. The bed can be rotated on trunnions, so that the polished surface can be carried away from the damp bands when not in use, and also for cleaning. The band is held against the heated surface at two places with considerable

are found to be properly dried by once passing through. The band is said to last for 12 months, but is expensive to renew. The use of this machine is said to consume little steam; but there does not appear to be any reason why this should really be the case.

The machine illustrated in Fig. 16 consists of four steam chests, or a smaller number, connected together by an end chest, and of an endless band of cotton duck, which is so guided by rollers as to pass over all the steam-chest surfaces and to be pressed heavily against the recesses of the end chest by means of padded rollers. A lower roller, *B*, is used for regulating the



A COLLAR AND CUFF IRONING MACHINE, MADE BY THE TROY LAUNDRY MACHINERY CO., LTD.

band, so that it runs true or straight, without working either to the right or left. Another roller, *A*, is arranged for keeping the band properly stretched. Although relatively to the size of the machine a large extent of heating surface is here presented for drying the linen, yet over most of the surface there is little pressure of the linen against it.

The machine shown in Fig. 17 is a curious combination of those shown in Figs. 15 and 12 or 13. The cylinder is of considerable size, namely, 48 in. in diameter, and is heated by steam. An endless band of light canvas carries the linen against the under side of the cylinder, after it has been acted on by the top pressure-rolls; and, in combination with another endless band or apron, carries it back again, so as to deliver it on the opposite side to that where it was fed in. The machine was designed with a view to getting through a large quantity of work. It is, of course, expensive, and would appear to have most of the faults of the two machines of which it is a combination.

The machine illustrated in Fig. 18 is a combination of a Decoudin with that shown in Fig. 15. It has two beds and two felted rollers, so arranged as to act on both sides of the linen, having steam in the beds only and not in the rollers. After the linen has thus been doubly acted on, it is carried by an endless band of canvas around and against nearly the whole circumference of the large heated cylinder, which does not revolve, and is then carried some distance beyond it, so as to give time for the steam to clear away before it is delivered to the receiver. This machine appears to have many recommendations, and, at a speed of 30 feet per minute, will dry ordinary sheets with one pass through. It is the simplest machine there is of the kind. The

difficulty the steam has in getting away is still a fault in these later machines.

An arrangement has been tried for blowing away the steam from the clothes directly they have passed from the heating surfaces, but its efficiency is doubtful. Fig. 19 shows an ironing machine which ought to dry linen after once passing through. It is really two Decoudin ironers combined into one, and thus does away with the handling of the goods between each feed. The special point about it is the endless band on the first roller for preventing the linen from clinging to the roller. The rollers are both padded, and hence the band should allow the moisture to pass through it into the padding of the first roller, unless it can absorb largely itself. One fault is that the moisture, which in its heated state would evaporate, has not time to do so while the linen is passing between the rollers; but this is overcome, at least partly, by the surface between the two rollers being heated. The speed of the machine is about 17 feet per minute. It appears to be a genuine attempt to overcome the loss of time and labour in passing linen twice through a Decoudin ironer, and has the merit of presenting a good arrangement for feeding the linen in.

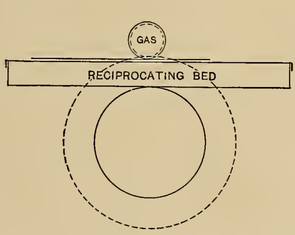


FIG. 20.—COLLAR AND CUFF IRONER

In comparing the merits of these various machines, it may be noted that, provided the metal surfaces are well polished, there is no need to fear the linen sustaining wear when drawn over them, even when under considerable pressure such as is used in the Decoudin ironer. So far as economy is concerned, it must be remembered that the same number of attendants are required whether the machine does much or little work; and also that there is a practical limit to the speed at which a machine can run, because if too quick, the articles cannot be fed in evenly. The machine is required to deliver the articles

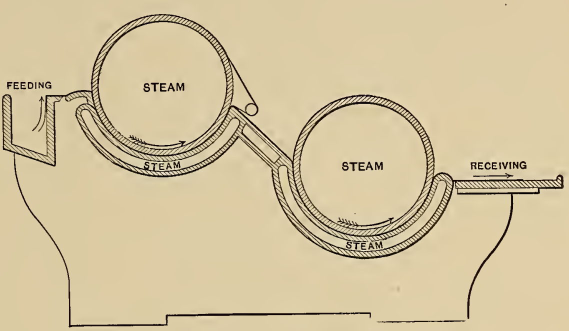


FIG. 19.—TWO DECOUDIN IRONERS COMBINED

free from creases, of correct and even shape, and with a good finish on the surface. The greater the heat, the better is the finish of the surface.

So far as speed of working is concerned, any machine which runs at 25 feet per minute, and dries the linen properly by once passing through, is not far wrong. The value of the heating surface is governed by the degree of pressure with which the article is held against it; by the temperature to which it is heated,—that is, by the pressure of steam it will stand; and by the ease with which the water can be got away from it in the form of steam. A further point is the ease with which goods can be fed in correctly.

One difficulty, not yet satisfactorily overcome in most machines, is in finishing starched goods, owing to their sticking to the padded surfaces. The calendar, however, is satisfactory in this respect. On the whole, the machine shown in Fig. 18 appears to present many good qualities, and to be fairly free from faults.

In Fig. 20 is shown the principle of working of a collar and cuff machine,

which, in a general way, appears to be a nearly perfect machine of its kind. The main parts are a horizontal rigid bed, padded on its top surface, and, when working, supported on a roller beneath, by which it is made to slide forwards and backwards; and a hollow upper roller, made of cast metal, and heated by gas jets inside, against which, by raising the lower roller by a treadle, the upper padded surface of the bed is pressed. The goods, laid upon the padded surface of the bed, are dried by the heat of the hot roller above.

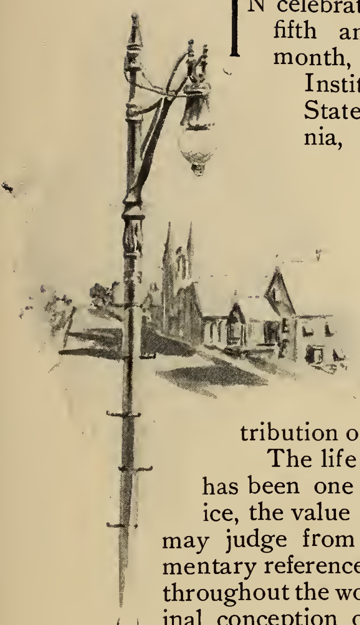
It is important for the top roller to be made of exceedingly fine-grained metal, and to be turned perfectly true and highly polished. The roller is driven at a greater surface speed than that at which the bed travels, thereby causing a skid upon the linen that is being ironed; the relative speed varies in different machines, but nearly 2 to 1 is often used. The ease with which the machine is handled, and the quantity of work it gets through, are so great that it is now in extensive use. One difficulty connected with it is in the bearings of the heated roller; owing to the pressure with which the bed is forced up against it, and to the great heat at which it is worked, the bearings are troublesome to lubricate and liable to grind.

An ironer for body linen, much used in America for general work and in England for flannels, consists of two equal rollers, each about 6 in. in diameter, made to project horizontally up to 3 feet overhand from the frame of the machine, which are both made to revolve at equal speed. The top roller is polished cast iron, turned true and heated inside by gas jets; the lower roller is solid and padded, and can be raised to press up against the upper, or lowered away from it, by means of a treadle; the act of lowering puts it out of gear. In order to get all parts ironed equally of the article to be finished, it is moved about continuously by hand while still between the rollers, but while they are not pressed together; and inasmuch as the article is always on the bottom roller, the loss of time is small for shifting the article, so as either to iron any portion a second or third time over, or to bring a fresh part to be ironed. The rollers have a surface of about 25 feet per minute.

In such a wide subject as that of this paper the author has endeavoured, as far as possible, to deal only with the principles of the machines described, and to avoid unnecessary details of laundry work in general. The numberless small machines which find favour in America for ironing special parts of garments have purposely been passed over, as have also the ingenious machines for starching, which appear to be slowly forcing their way into use.

THE FRANKLIN INSTITUTE

By John Birkinbine, President of the Institute



IN celebrating its seventy-fifth anniversary this month, the Franklin Institute, of the State of Pennsylvania, takes its place among the old organisations in the United States, and a brief glance into its history and at what it has accomplished is offered as a contribution on this occasion.

The life of the institute has been one of public service, the value of which, if one may judge from many complimentary references, is recognised throughout the world. The original conception of the organisation resulted from the failure of a young man, "the owner of a workshop, without a mechanical education, without a mechanical idea," to secure admission to a local association of mechanics, because he lacked the prescribed qualifications for membership.

The time was propitious for an organisation such as the Franklin Institute, with its object "the promotion and encouragement of manufactures and the mechanical and useful arts," for, before the year 1824 closed, the institute had five hundred members, and had been chartered by the State of Pennsylvania. Within two years after its organisation it had erected the substantial marble front building on South Seventh street, Philadelphia, which has continued to be its home to the present time, but which is overcrowded by its valuable collections and is insufficient for properly carrying on its work.

Before the institute was a year old, it held an exhibition in Carpenter's hall, concerning which the venerable Mr. Frederick Fraley, the only surviving charter member, says:—"It attracted large crowds of people who hitherto had no conception of the extent and variety of our home productions, and reacted in many curious and unexpected ways to bring producers and consumers together, and to diffuse knowledge of our skill and resources." This, the first exhibition of American manufacturers, held in October, 1824, has been followed by twenty-eight exhibitions, given under the auspices of the Franklin Institute.

The exposition of the present date has assumed proportions which dwarf the earlier efforts of the Franklin Institute, but several of those given under its auspices have become historical because of their extent, their distinctive character, and the liberal patronage which they have received.

Only those who have been associated with the organisation and conduct of industrial exhibitions realise the work demanded, nearly all of which was gratuitous service rendered by members of the Franklin Institute. The movement which culminated in the Centennial Exhibition of 1876, at Philadelphia, was started by the Franklin Institute, and its International Electrical Exhibition, in 1884, contributed the impulse which resulted in placing the United States in a leading position in the utilisation of electricity.

The following is quoted from the introductory to an admirable history of the Franklin Institute, prepared by Dr. William H. Wahl, who is the secretary of the Institute:—

THE FRANKLIN INSTITUTE, PHILADELPHIA

"It was the first institution of its class to be established in the United States, and, though embodying in the scheme of its organisation many of the features of the so-called 'mechanics' institutes,' its scope was more broadly gauged, and its working methods were constructed on a higher plane than these. It was, if the comparison is permissible, the result of a compromise. Neither the mechanics' institutes which sprung into existence like mushrooms about the time when the organisation of the Franklin Institute was being considered, and which were devoted almost wholly to the instruction of artisans by means of lectures and classes, nor the exclusive societies of those learned in the sciences and arts, answered to the ideas and needs of the founders.

An instrumentality was sought through which these two elements, so diverse in character, yet potentially capable of being mutually so helpful, could be brought into fraternal relations,—a platform was needed, broad enough, and strong enough, to accommodate professor and layman, master and workman, side by side, without incommoding either; in brief, an institution was wanted which should have inscribed on its corner-stone, 'Science with Practice; Practice with Science.' "

This association of the practical and technical members has continued throughout the life of the institute, and is undoubtedly the prominent reason for the success which has favoured the organisation. For a time the technical was overshadowed by the practical element, and believing that in late years the reverse has prevailed, the management have taken steps to keep the institute in close touch with the practical mechanic who earns his living by working at his trade.

Its library, probably unexcelled in technical works, and embracing 50,000 bound volumes and 36,500 pamphlets, maps, and charts, is now housed in metallic stacks in a portion of the building made fire-proof. Many of the volumes in this library could not be replaced if destroyed, and the series of technical society transactions or publications are remarkably complete. Among the valuable books are presentation copies with the autographs of distinguished authors.

This protection to the library has been a late accomplishment, and it greatly relieves the anxiety of the management, as well as of those who, having occasion to use the books, recognise their value. While the library is maintained primarily for members of the institute, it is available to the public for a portion of each day, and students following any special line of investigation have always been met in the spirit of liberality, dictated by the desire of the membership to lend the facilities and influence of the organisation to assist all advances in science or practice.

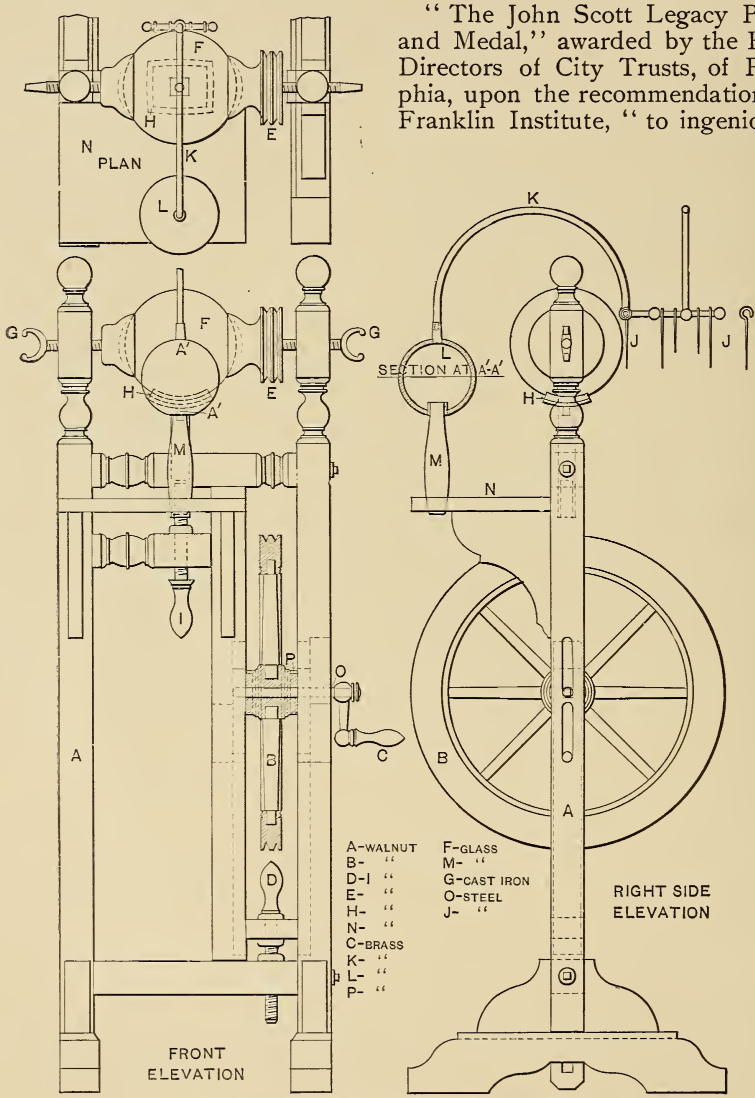
At its monthly meetings new inventions, or the results of scientific investigations, are considered and discussed, and many startling discoveries in physics or chemistry, or renowned applications of mechanical energy, first became known through their presentation at these meetings. The lecture-room of the Franklin Institute is memorable for the numerous instances when such discoveries, inventions, or investigations have been introduced, and in it men, now prominent, made their first appearance before an audience. The first meeting, which resulted in the formation of the American Association for the Advancement of Science, was held at the Institute in 1848.

The lecture courses have been remarkable for the many famous scientists who were, and are, ready to exploit their views to a constituency which represents such an honourable history. The general government, the legislature of Pennsylvania, and the municipal authorities of the city of Philadelphia have repeatedly called for the aid of the Franklin Institute in matters affecting the public welfare; and yet no financial assistance has ever been asked by, or given to, the institute from either of these sources beyond, in a few instances, sufficient to defray actual expenditures in following out special investigations committed to it.

With the possible exception of the numerous exhibitions held, no feature of the work of the Franklin Institute has been more productive of good results than its Committee on Science and Arts, which, for over half a century, has carried on scientific inquiries referred to it by the institute, and has critically examined and reported upon thousands of inventions or technical studies. Forty-five of the ablest members of the institute (fifteen being elected by ballot each year) constitute the Committee of Science and Arts, and, without compensation, laboriously make the necessary investigations. This work has resulted in exposing many fallacies, in suggesting how good, but apparently impracticable, ideas may be modified and utilised, and in indorsing much that is meritorious by diplomas and medals

which it has authority to grant,—recognitions which are prized in all countries.

Many prominent inventors in the United States and in Europe could be mentioned who have been recipients of



BENJAMIN FRANKLIN'S ELECTRICAL MACHINE

medals from the Franklin Institute after investigations by the Committee on Science and Arts. The following awards are granted by the Franklin Institute:

"Certificates of Merit" for inventions, discoveries or productions which may be deemed specially worthy.

"The Edward Longstreth Medal of Merit" for the encouragement of invention, and in recognition of meritorious work in science and the industrial arts.

"The John Scott Legacy Premium and Medal," awarded by the Board of Directors of City Trusts, of Philadelphia, upon the recommendation of the Franklin Institute, "to ingenious men and women who make useful inventions."

"The Elliott Cresson Medal" for "either some discovery in the arts and sciences, or for the invention and im-

provement of some useful machine, or for some new process or combination of materials in manufactures, or for ingenuity, skill or perfection in workmanship."

"The Franklin Institute Medals," either of silver or bronze, awarded as "the reward of skill and ingenuity," in many instances in connection with the exhibitions held by the institute.

"The Uriah A. Boyden Premium," a special award of one thousand dollars, to "any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity."

With this one restriction noted, there is equal opportunity for men or women, Americans or citizens of other countries, calling upon this committee for an opinion on an invention or process with the certainty of having it receive fair, conscientious investigation, and, if worthy, an award which money cannot purchase. The record of the work of the Committee of Science and Arts and the appreciation of its awards are its best indorsements.

The collection of instruments and models embraces many that are valuable and curious. Among the former are Benjamin Franklin's electrical machine, the construction of which is illustrated on the opposite page, and other early electrical apparatus. The models comprise Oliver Evans' high-pressure steam engine; Saxton's magneto-electric machine; an early Morse printing telegraphic instrument; Bain's printing telegraph instrument; early forms of Brush arc lamps; an original Sawyer-Mann incandescent electric lamp; Dr. Hare's lightning rod; and a model of Stephenson's locomotive, No. 1. Benjamin Franklin's sword and other interesting Franklinana are among the collection. Perpetual motion machinery and other mechanical vagaries are also found among the curious models harboured by the Institute.

Since 1825 the Institute has maintained a drawing school, which, in late years, has averaged, at its semi-weekly sessions, 80 students. It is believed to be the oldest school of instruction in mechanical and architectural drawing in the United States, and the thoroughly practical character of its instruction has gained for it a high reputation. Many of the leading American mechanical engineers and machine builders owe their first scientific training in the mechanic arts to this school. Notwithstanding the establishment of other drawing schools as features of educational institutions in Philadelphia and vicinity, the interest in this study has been maintained in the Franklin Institute.

The illustration of the Franklin electrical machine, reproduced opposite, is the work of a student of the drawing school. The machine consists of a wooden base, frame, *A*, and bracket, *N*, supporting a wheel, *B*, operated by a crank, *C*, which transmits motion by cords passing over the wooden drum, *E*, to a glass globe, *F*. This globe revolves on the adjustable centres, *G G*, against a felt rubber, *H*. The electrical fluid is collected by the steel fingers, *J*, and conveyed by the bent brass rod, *K*, to the brass globe, *L*, which is insulated on the glass post, *M*. The tension of the driving cords is adjusted by the wooden screw, *D*, and the friction of the rubber on the glass ball is controlled by a similar screw, *I*. The machine occupies a floor space 24 inches by 20½ inches, and has a height, over all, of 5 feet, 7 inches.

The efforts to advance instruction in special lines resulted in the institute founding the School of Design for women and establishing the first High School in Philadelphia. It also aided in founding the Pennsylvania Museum and School of Industrial Art.

The Institute is now co-operating with the Philadelphia Commercial Museums in the contemplated exposition of American products for export, to be held in connection with the proposed congress of commercial delegates of foreign nations.

At present there are active sections devoted to chemistry, electricity, mining and metallurgy, mechanics and engineering. At the sessions of these

sections the strictly technical lectures are presented, those of a more popular character being now delivered before the institute. In the latter the Young Men's Christian Association co-operates, and places its commodious auditorium at the command of the institute.

In addition to the committees having charge of the library, the Franklin Institute *Journal*, and the lecture courses, there are those who devote attention to models, to meteorology, to manufactures, etc. The management of the institute devolves upon a board, consisting of a president, three vice-presidents, a secretary and treasurer, and twenty-four managers, one-third being elected annually. This board has committees who look after the various details of membership, finance, sections, exhibitions, instruction, care of property, etc. The salaried officers are a secretary, an actuary, and a librarian, with necessary assistants.

The *Journal* of the Franklin Institute for seventy-three years has been the medium of publishing to the world the proceedings of the institute and its sections, and also many of the lectures given before them, forming a unique record of scientific and mechanical progress. In it appears the first systematic record of American patents, attempted long before the United States government appreciated the necessity of collecting these, and the publication in the *Journal* of abstracts of specifications and claims of United States patents from 1826 to 1843 now affords the only available reference to this information. It is edited by a committee of the board of managers, with the assistance of the secretary.

Among the special inquiries which have been undertaken by the Franklin Institute are the following:—

It established a uniform system of machine screw threads, subsequently adopted by the government as the United States standard, and now in general use throughout the country, with a prospect of becoming international. This alone has been worth many millions of dollars to the manufacturers of the United States.

It made tests of the strength of materials for the United States government, the results of which have been of great value to the manufacturing interests.

It investigated the causes of explosion of steam boilers, at the request of the United States Treasury Department.

It was the pioneer in making, recording and publishing, systematically, meteorological observations, culminating in the establishment of the United States Weather Bureau.

It investigated the various forms of water-wheels for augmenting the economical value of water powers.

The law of Pennsylvania relating to the system of weights and measures was enacted as a result of the report made by the institute, at the request of the legislature of the State of Pennsylvania.

In response to an invitation from the city councils, it nominated an expert commission to report on a future water supply for Philadelphia, and, conforming with the desire of the Board of Health, it has recently investigated and reported upon the subject of the abatement of the "smoke nuisance" in Philadelphia.

An examination of the roll of members indicates that many of the most successful business men and learned specialists of the United States have been, or are now, on its list, for membership is not restricted to the City of Philadelphia, or State of Pennsylvania, nor are women excluded.

Its constitution provides that "the members of the institute shall consist of manufacturers, mechanics, artisans and persons friendly to the mechanic arts," and the organisation is defined by Dr. Coleman Sellers, past president of the institute, as "a democratic, learned society, in which all who desire to reap its benefits, or to aid in its great work of promoting the mechanic arts, can join. Learned men join our society and in its hall come in contact with those who may be unlearned so far as books are concerned, but better informed in some special art or trade. Theory and practice are brought together, and each helps the other."

Upon the membership of the institute, now numbering 1800, rests the burden of its maintenance, for its other sources of income are very moderate.

The institute is endowed far below its actual needs and aspirations for expansion. Receiving no financial aid from the city, State or general government, with only a few small endowments, most of them confined to special purposes, its work is restricted practically by the annual contributions of its members, but it is hoped that the efforts being made to suitably endow it and provide a more commodious building in the near future may prove successful.

Bequests to the institute, life and permanent membership fees and initiations, and fees of non-resident members are considered as permanent funds, and are administered by trustees who pay interest and dividends to the institute as such fall due. The permanent funds of the institute are thus well cared for and freed from influences or changes of a temporary character.

Franklin's activity in organising the American Philosophical Society and the Philadelphia Library has resulted in the institute which bears his name being credited to him. It, however, came into existence after his death, and its founders chose for it the most fitting name, that of the illustrious printer, statesman, philosopher, — the synonym of broad utilitarianism,—Benjamin Franklin.

Within a few minutes' walk of the Franklin Institute Hall lie the ashes of "poor Richard," and it may be confidently claimed that the spirit of helpfulness and of patient investigation which he exhibited in life has been constantly present in the work of the institution which bears his name.

ELECTRIC UTILISATION OF WATER POWERS

By L. D. W. Magie

Condensed from a Paper Read Before the Canadian Electrical Association

THE pioneer work in electrical transmission was done with the direct-current system, and too much credit cannot be given for achievements attained. But although in a few instances the distance covered by the direct-current system has been up to 12 miles, yet, on the whole, for commercial reasons it has not been desirable to transmit power by direct current to a distance of over 2 miles, and the advisability of even this is looked upon doubtfully to-day.

The amount of copper required for the transmission of power is directly proportionate to the amount of power to be transmitted, and also directly proportionate to the square of the distance for a given efficiency. This may be stated commercially by the amount of copper required for transmitting, say, 100 horse-power for both one mile and ten miles, the loss in transmission to be 8 per cent. and the pressure to be 500 volts.

For each leg of a one-mile circuit there would be required two No. 0000 wires, or four No. 0000 wires, each one mile long, weighing 13,312 pounds, which, at 15 cents per pound, would cost $2,300. For each leg of the 10-mile line there would be required twenty No. 0000 wires or forty No. 0000 wires, each 10 miles long, weighing 1,531,200 pounds, which, at 15 cents per pound, would cost $230,000, or the power would cost, at 10 per cent. interest and depreciation on copper alone, $2.30 per horse-power annum in the first instance, and $230 per horse-power annum in the second case.

If, however, the pressure be raised to 5000 volts, and be used for transmitting 100 horse-power for 10 miles, the condition would be entirely different, for instead of forty No. 0000 wires, each 10 miles long, there would be required for each leg but one No. 4 or two No. 4 wires each 10 miles long, weighing 15,300 pounds, which, at 15 cents per pound, would cost $2,300, or the same as transmitting the same amount of energy only 1 mile at 500 volts.

The primary or fundamental question is to ascertain the point at which transmission of water powers will be a source of profit to the investor. The cost of electrically transmitted power is represented by the interest on the capital invested; the depreciation; the maintenance; the operating expenses, and numerous other small contingencies, and besides, in some cases, the amount of money that has to be expended for water and land privileges. The sum of these accounts per year, divided by the amount of horse-power actually sold, will be the actual cost per horse-power for the case in question.

Probably the greatest competitor to electric power is steam power. In a few instances power derived from gas or petroleum engines may also compete. The cost of producing steam power in any given locality is a fair criterion by which to determine how much electric power should cost. The cost of power produced from other sources can usually be disregarded.

The cost being ascertained at which steam power can be produced in a given locality, it can be determined what cost per horse-power may be expended on the construction of an electrical transmission plant to make it profitable to the investor, provided, again, a sufficient market can be obtained for power.

When electrically transmitted power does not cost more than $100 to $140 per horse-power installed, the investment is apt to be a profitable one, providing, of course, it is properly managed.

The first item of expense is the amount required for water privileges. In some cases this is rather an unimportant consideration, while in others it is the chief expenditure, for it may involve the buying of thousands of acres of land surrounding the stream, because the necessary dams may cause to be submerged a great deal of valuable land, or large tracts have to be bought for building storage reservoirs, or the right of way for pipe lines, etc., have to be secured. When land is cheap these considerations are often not objectionable, but where good farming land, or land valuable for other reasons, has to be thrown to waste, the question may be a perplexing one.

The cost of the dam, power house, and hydraulic machinery is, as a rule, dependent almost entirely on the characteristics of the stream being utilised. Entering into the question is the amount of water in the stream, both under normal as well as abnormal conditions at various seasons of the year; also the head or fall, and whether it is dependent on natural conditions or requires the building of large dams. Generally speaking, other things remaining equal, generating plants, comprising the power house, hydraulic and electric machinery, as a whole cost less as the head increases, until certain limits have been reached. When the head is low, ranging from 4 to 10 feet, it requires a comparatively large wheel for a relatively small amount of power, and then only slow speeds can be attained. When large units are desirable, a number of such wheels must be coupled together in order to get the required power. The speed required can be raised or lowered to a certain extent, depending on the size of the wheel. If higher speeds at low heads be desired for large units, many wheels must be operated together, requiring not only a great deal of room, and consequently a larger power house, but considerable line shafting, gears, couplings, etc., which not only increase the initial cost, but increase the cost of operation and maintenance of the plant, as well as introduce another source of inefficiency. With higher heads a larger amount of power can be obtained from fewer and smaller wheels, with higher speeds, and,

therefore, cheaper generating apparatus.

The cost of generating apparatus for a given capacity, other things remaining equal, is almost directly proportional to the speed at which it runs, and for this reason it is always desirable to refrain from too low speeds wherever possible. A good engineer will hardly warrant the expenditure of, say, $15,000 for a 300-kw. generator to run at a speed of, say, 75 to 100 revolutions per minute, when a machine just as good in every respect, and sometimes better (because it is a standard size), can be bought in belted units for $5000.

The next item of considerable expense is the transmission line. The poles, with their appurtenances, exclusive of wire, will cost between $250 to $500 per mile, varying according to circumstances. Rights of way for the placing of poles may often be expensive. The transmission wire must be considered separately.

The cost of the transmission wire is often the most important part, but is always different with each case, dependent, as it is, upon the amount of power to be transmitted, the transmitting voltage, distance, and the allowable loss. As a whole, it is always best to keep the transmitting voltage as low as possible and still keep within commercial conditions. Many people are carried away with the idea that if they could only use high voltages the cost of transmitting would be reduced to a minimum. It must be borne in mind that with the use of the higher voltages the cost of insulators increases, the electrical apparatus necessarily costs more, and, moreover, the risks are greater throughout the system, and consequently more skilled attendants are necessary to look after the plant. All of these items have to be carefully considered before looking into the possible saving of copper on the line.

For mechanical reasons, a wire smaller than No. 6 B. & S. should not be used for line work. More cautious engineers will say it should not be smaller than No. 4 B. & S. It is foolish to attempt to use voltages which allow the use of smaller than No. 6 wire. Where a shut-down would mean heavy damages, it might be advisable even to use a wire not smaller than a No. 2 B. & S. If these facts are always borne in mind, the question of voltage will oftentimes adjust itself, and the use of very high voltages will not be found necessary, unless the transmission be for especially long distances, and the amount of power particularly large.

CHARLES HENRY CRAMP

A Biographical Sketch

PROBABLY no other naval architect and shipbuilder anywhere is to-day more widely known than Charles Henry Cramp, the head of the great American ship and engine building establishment of William Cramp & Sons, of Philadelphia. His father, William Cramp, was the founder of the shipyard which bears his name, and Charles, who was born in 1828, is the oldest of a family of eleven.

According to the National Cyclopedia of American Biography, from which, through the courtesy of its publishers, Messrs. James T. White & Co., of New York, the particulars here given have been taken, William Cramp was a remarkable man, and his monument is the great shipyard which has been expanded and improved until it is among the most complete and perfect in the world. The struggles which William Cramp had to make in achieving what he did, naturally made its impress upon the character of his sons, and particularly upon Charles, who, being the eld-

est, necessarily had the greatest share in them.

Charles H. Cramp's schooling was thorough, and as soon as he had completed an extensive academic course, under such instructors as Professor Alexander Dallas Bache, he engaged with his father in the profession of naval architecture. He did not cease to be a student when he left school. After reaching manhood, by such opportunities of study as he could find during a business career of far more than ordinary assiduity, he studied the modern languages and perfected himself in the higher mathematics, not only as applied in the problems of naval architecture, but in their general range as well.

Mr. Cramp is not only head of the concern, but is also its naval architect, and has always been recognised as one of the heads of that calling on the American side of the Atlantic, while his attainments and achievements do not suffer by comparison with the best reputations in the art in Europe.

Mr. Cramp is a naval architect not merely in the work of evolving designs for others to execute, but in every department and detail of actual ship construction, from draughting room and mould-loft practice and modelling, to superintending the shipyard work in every branch. This unremitting practice, covering, as it has, the great radical transitions from sail to steam, from wood to iron, from iron to steel, and coupled with the gigantic strides meantime in the development of steam propulsion, has brought Charles H. Cramp to the prominent position which he holds among naval architects.

His chief claim to permanent distinction rests on his share in the reconstruction of the United States Navy, and the revival of the American merchant marine. Early in the history of the new navy, the Secretary of the Navy Department availed himself of Mr. Cramp's experience and skill. The secretary at that time was Hon. William C. Whitney, a man of affairs in the broadest sense, and he inaugurated, at the outset of his administration, several radical departures from the traditional bureaucracy of the department. Among these was his policy of taking counsel of civilian shipbuilders and marine engineers in matters affecting the design of new ships.

For many years after the Civil War no effort had been made to keep abreast of general progress in the art of naval construction elsewhere. With few exceptions, the Navy Department had been content to reproduce from time to time, under the guise of "repairs," the obsolete wooden craft of the old navy, such "repairs" being generally the construction of a new ship on the old lines and under the old name, using perhaps one plank or even one bolt only of the old ship for the sake of form. Thus, neither the officials who had charge of designing, nor the workmen who built the vessels in the navy yards, had opportunity to learn or practice the improvements and innovations which were occurring abroad while American private shipbuilders, systematically excluded from naval works, found their aspirations disparaged and their efforts discouraged.

To this situation Mr. Cramp proved a signal exception. Fortunately, during the period immediately preceding the reconstruction of the navy, Mr. Cramp, in addition to the naval work above referred to, had built and equipped four cruisers for the Russian Navy. These ships, though brought out under circumstances of emergency, due to the Turkish war and its threatened consequences, were creditable vessels of their class and date. The experience gained in their construction, and from dealings with the accomplished Russian officers who supervised them on behalf of the Imperial Government, together with constant study and observation of current work and progress in naval architecture and marine engineering in other countries, equipped Mr. Cramp in these respects to a degree quite exceptional among American shipbuilders.

In rapid succession were built the *Yorktown*, a gunboat of 1700 tons, the hull designed by Navy Department, with triple-expansion engines designed

by Cramp; the *Vesuvius*, a dynamite torpedo vessel of 890 tons, the hull and machinery designed by Cramp; the *Baltimore*, protected cruiser of 4400 tons, on designs purchased by the Navy Department; the *Philadelphia*, a protected cruiser of 4400 tons, hull and machinery by Cramp; the *Newark*, a protected cruiser of 4000 tons, hull by the Navy Department, the engines by Cramp; the *New York*, an armoured cruiser of 8150 tons, Navy Department design of hull, and machinery modified by Cramp; the *Columbia*, a protected cruiser (commerce destroyer) of 7350 tons; the *Minneapolis*, a sister ship to the *Columbia;* the *Indiana*, a battleship of 10,400 tons; the *Massachusetts*, a sister ship to the *Indiana;* the *Brooklyn*, an armoured cruiser of 9150 tons, an enlargement on the *New York* type; and the *Iowa*, a seagoing battleship of 11,300 tons.

This is a fleet of eleven vessels of war, ranging in type from the torpedo cruiser to the first-class battleship, embracing nearly 80,000 tons of displacement and 147,000 indicated horsepower.

Concurrently with this enormous work Mr. Cramp was compelled to enlarge his plant and expand his organisation to meet its requirements. When naval reconstruction began, Cramp's shipyard at Philadelphia, including the basin, dry dock and marine railway, covered 13.7 acres of ground, employed 1600 men, and was capitalised at half a million dollars. That was in 1884. Ten years later it covered 31 acres of ground, employed 6000 men, and was capitalised at five millions of dollars. But this is not all. Its facilities had been extended to the general manufacture of machinery and of ordnance. It had passed from the status of a simple shipyard to that of one of the greatest and most complete naval arsenals in the Western hemisphere.

Pending this tremendous activity Mr. Cramp found time to press upon public attention the condition and needs of the American merchant marine. With tongue and pen, in season and out of season, he urged upon the people and upon Congress the policy of regaining the rank of the United States as a commercial nation on the high seas. At last his efforts were rewarded by the adoption of a policy which bore fruit in the building of American transatlantic greyhounds to rival the proudest creation of foreign skill. He has said that the summit of his ambition will have been attained when he can cross the ocean in an American-built ship, capable of showing her wake to anything afloat.

If you ask him what he wants for his monument he will tell you that it is the chimneys of Cramp's shipyard, and for his epitaph he will be content with the trial record of his fastest ship. At work Mr. Cramp is the ideal executive. His judgment in the selection of men is of the best. He has the Napoleonic faculty of making the members of his staff do things as well as he could himself. He never relies on any man until sure that he is the right one in the right place, and then his trust is absolute. He has also the faculty, more rare even than the other, of inspiring the most perfect loyalty to himself and his fortunes.

Current Topics

In the January number of this magazine Mr. W. F. Durfee, C. E., described Goguet's supposition as to the means employed to raise the stones of the Pyramids, and incidentally referred to the statement by Herodotus that these stones, some of which were over 30 feet long, were elevated by "machines

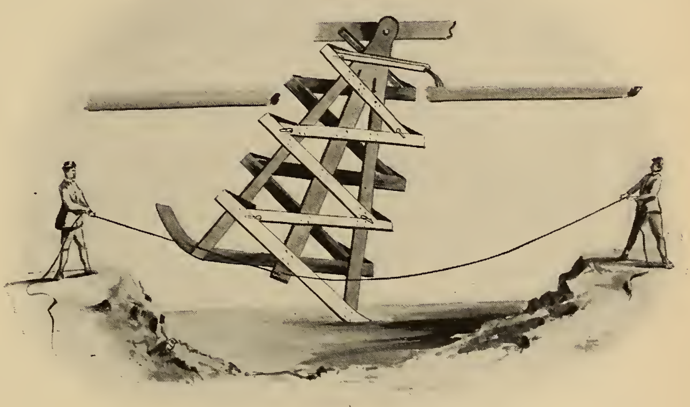
A POSSIBLE METHOD OF RAISING THE STONES OF THE PYRAMIDS

made of short pieces of plank." It may not be uninteresting, therefore, to refer to the little sketch on this page, supplied by Mr. Durfee, which serves to show how a simple employment of such "short pieces of plank" would enable a comparatively small number of men to raise large masses of stone with absolute safety. The sketch, as Mr. Durfee says, is self-explanatory to any one familiar with the dressing of stone. If the pyramid builders had employed short pieces of plank in the way indicated they could have made the stones almost raise themselves, by seesawing them, first on one pile of plank, and then on the other. As shown, the left-hand pile of planks is acting as a fulcrum, the left end of the stone being depressed. This permits the insertion of one or more planks beneath the stone on the top of the right-hand pile, which, then, in its turn, can be made the fulcrum for the stone; and thus gradually and safely it can be raised to the level of the next higher course of masonry. Arrived there, it could readily be slid, or tilted sideways, onto the top of that course, and the alternate tilting process could be continued until the stone had arrived at its intended height, when it could have been conveyed on rollers to the place for which it had been shaped. This method of raising stone is not a mere hypothesis, as it is in daily practical use in every "stone-yard" and building-stone quarry; and doubtless it has been handed down through countless generations of stone workers from an origin too remote for even the imagination to conceive. Whether this method was actually used by the Pyramid builders

cannot, of course, be asserted; but it is suggested as a simple, inexpensive, safe and effective mechanical expedient, that satisfies the description of Herodotus.

It may be urged that a few short pieces of plank, used as contemplated in the sketch, cannot properly be called a machine; but this term is really a very comprehensive one, and is properly applied to every mechanical contrivance for employing or directing force, or doing work, and, therefore, the pieces of plank, used as shown, are but simple machines. The ancients chose the simplest and safest means to attain their ends. They hastened slowly, but progressed surely in all their constructions. They built for the eternities. We look upon their work with astonishment, but fail to profit by its silent, though eloquent, instructions, and content ourselves by acknowledging our inferior skill when we admit that there is no probability that any nineteenth-century structure will compare in endurance with the Pyramids, which have been the focus of a world's wonder for three thousand years.

Of the several kinds of pendulum arrangements for raising water that have been proposed and used at different times, an interesting example is shown in the little sketch on this page, which was published and described originally by Belidor, considerably more than a hundred years ago. According to data given in Ewbank's work on "Hydraulics and Mechanics," the machine consisted of a number of gutters, open at both ends, permanently connected to and over one another in a zigzag direction, so that while one end of the lowest dipped in the water, its other end inclined upwards and was united to the lower end of the next one, which also inclined upwards, but in an opposite direction, and was united to the next, and so on, the length of each diminishing as it approached the top. In the bottom of each an opening was made, covered by a flap or valve to prevent the water, after it had once passed through,



A PENDULUM WATER-RAISING MACHINE OF THE SEVENTEENTH CENTURY.

from returning. All the gutters were secured to a wooden frame suspended from a beam, so that by pulling the cords alternately, the whole arrangement could be made to oscillate. When pulled to one side, one of the lowest gutters dipped into the water and scooped up a portion of it, to facilitate which the end was curved. As the gutter rose, the liquid ran along to the farther end, and, passing through the valve, was retained till the motion was reversed, when it flowed down to the next gutter, and, passing through its valve, was again continued in the same manner to the next, entering, at every oscillation, the gutter above, till it reached the highest. From this it was discharged into a reservoir over which the last gutter was made to project. As shown in the sketch, there is a double set of gutters, so that a continu-

ous stream of liquid can be discharged into the reservoir. The machine was probably more ingenious than useful, and does not appear to have ever been employed extensively. Mention is made of another contrivance, similar to this one, except that square tubes were used instead of open gutters. These tubes were all of equal length, and were attached to a rectangular frame, suspended and worked in the manner just described.

EVERY now and then there are opportunities for learning how immeasurably better than we the ancients did some things which are now supposedly done in excellent ways, and even at the present time, in quarters remote from highly developed civilisation, results of various kinds are sometimes obtained by ways and means which are admirably suggestive of the fact that it behooves us to be modest in our claims to superior accomplishments In a recent United States consular report, for example, made by Mr. Horace N. Allen, of Seoul, in Korea, an account is given of the Korean method of heating dwellings, which, in point of principle at least, is much ahead of many of the heating systems in every-day use all over Europe and America. In building their houses, the Koreans lay down a system of flues where the floor is to be. These flues begin at a fire-place, which is usually placed in an outer shed or connecting closed alleyway. From this fire-place the flues extend in a more or less curved direction, like the ribs of a round fan, to a trench at the rear of the room, which, in turn, opens into a chimney, usually located some distance from the house. Flat flagstones are then placed carefully over these flues, and the whole is cemented over and finally covered with the thick oil paper for which Korea is noted. This paper keeps smoke from entering the room, and a little straw or brushwood, used in the fire-place for cooking the rice, serves to heat the stone floor and give an agreeable warmth which lasts till the time of the next meal. Two heatings daily serve to give a comfortably warm floor, upon which the inmates sit in the daytime and sleep at night. By leaving their shoes at the door, they preserve the paper floor, which, from constant polishing, takes on a rich brown colour.

AMONG the poor, the rooms are little cubes of eight feet, but in more pretentious houses, there will be a suite of four of them, opening into one another by sliding doors. A suite of these rooms on either side opens upon a large room with a board floor, which is 18 by 18 feet or larger, and unheated. This is used for summer and at all times as an outer hall or reception room. The fuel burned by the Koreans is a mixture of fine coal dust and wet red clay, made into balls by hand. These balls when dry are used by foreigners in their stoves, the latter having been retained in preference to the native system, chiefly because the paper floors would not stand the wear of foreign shoes and furniture. According to Mr. Allen's report, German stoves were, at one time, much in favour, but the stove most commonly used now is one of American make, and even a few Koreans have begun to employ it. The fuel, poor though its quality, is very expensive, and kerosene stoves, therefore, are beginning to make their appearance, appealing especially to the native population, as they are neat and handy, and supply light as well as heat.

THE HYDRAULIC POWER HOUSE AT TIVOLI

(See page 345)

CASSIER'S MAGAZINE

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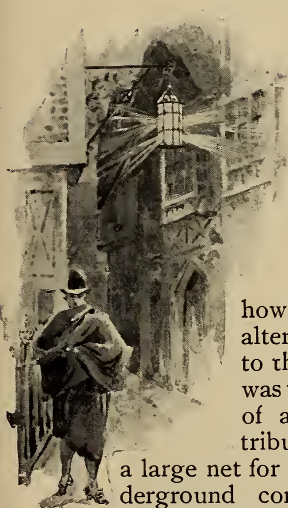
THE ROME-TIVOLI ELECTRIC INSTALLATION

By Alfred O. Dubsky



THE first electrical plant which was put in operation in Rome, in 1886, would to-day be considered a very modest one, for it had only two units of 150 horse-power each. These machines, however, were the largest alternators constructed up to that time, and the plant was the first demonstration of a high-potential distribution of electricity to a large net for a city supply with underground concentric cables and house-transformers for private consumers and street illumination. With this as a beginning were evolved the present electrical works, which have a total output of about 5000 H. P., and comprise a variety of interesting engineering features.

It should be noted at the outset, that the present electrical works of Rome consist really of two generating stations. The older, a steam plant, has a total capacity of 2700 H. P., and was built in the city of Rome itself, in the Cerchi quarter, on the site of the ancient "Circus Maximus." The newer hydraulic plant was erected at Tivoli, about 27 kilometres (17 miles) from Rome. The current generated in both stations is consumed in Rome for incandescent and arc lighting, for driving electric motors used by private consumers, and for the operation of the electric tramways.

The 2700 H. P. steam plant of Cerchi produces an alternating current of 2000 volts, which is distributed by four underground cables to the transformer stations. Step-down transformers, assembled in a number of secondary stations, provide the low-tension circuits with current. The other plant, at Tivoli, generates alternating current at a tension of 5500 volts, and the dynamos of this station, as already intimated, are driven by turbine-wheels. The electric power is conducted from there over a line of 27 kilometres to a large transformer station at the Porta Pia, one of the gates of Rome, where the voltage is reduced, according to the several uses of the current, for private consumers, municipal street arcs and for the tramway supply.

A. O. DUBSKY

The current coming from Tivoli is, therefore, divided to three distinct trans-

THE FALLS AT TIVOLI

former batteries. One of these is used to reduce the Tivoli current to 2000 volts, and this current is employed for the purposes of the private supply (house-lighting and motors). There are, for these purposes, four underground cables, starting from the Porta Pia station.

The second transformer battery also reduces the Tivoli tension to 2000 volts, as before; but these transformers serve only to feed the underground concentric cables used for public arc illumination. There are six arc circuits, each of these containing a maximum of 50 arc lamps in series. These lamps are used for lighting the public streets and places of Rome.

A third part of the current arriving from Tivoli is reduced to 400 volts, and is then turned into direct current of 550 volts by rotary converters. This direct current is used for the electric street railway service and a large storage battery system is in parallel with the direct current side of the converters for equalising the continuous current supply.

A fourth, and last, fraction of the available Tivoli power is used to feed four rotary converters of special construction which convert the 5000-volt alternating current directly,—without the intermediary use of any transformer,—into a continuous current of 550 volts. These converters work also in parallel with the storage battery for the tramway supply.

A special cable, shown by the dotted lines in Fig. 1, connects the Cerchi steam plant and the Porta Pia transformer station; this cable permits of supplying the Cerchi cable net with current coming from Tivoli, and also, in case of need, of turning into the cable net of Porta Pia current from the steam plant.

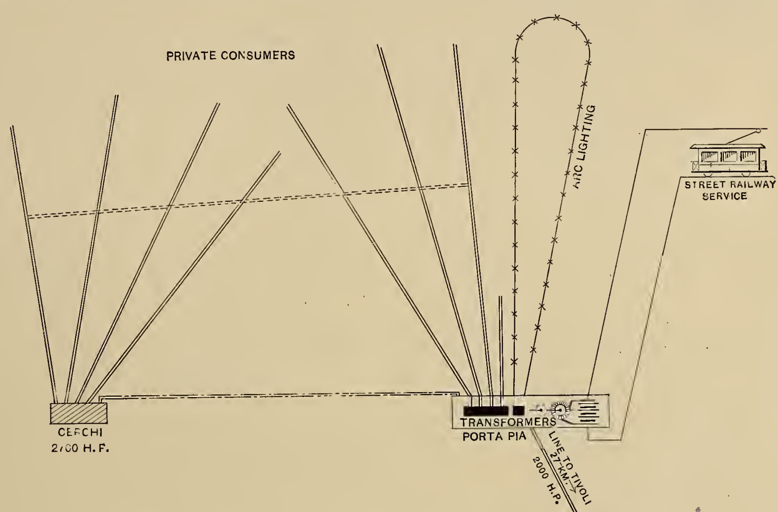


FIG. 1.—THE POWER AND TRANSFORMER STATIONS AT ROME

The electric circuits branching from Cerchi and Porta Pia intersect each other at several points in the town. At several of these places switches are provided enabling parts of these two systems to be connected either to one station or to the other. The current supply changes, of course, in the whole extended cable net according to the different seasons of the year, and the above mentioned proceeding is a good way to distribute the load conveniently upon both central plants.

PROF. G. MENGARINI

The electrical and hydraulical part of

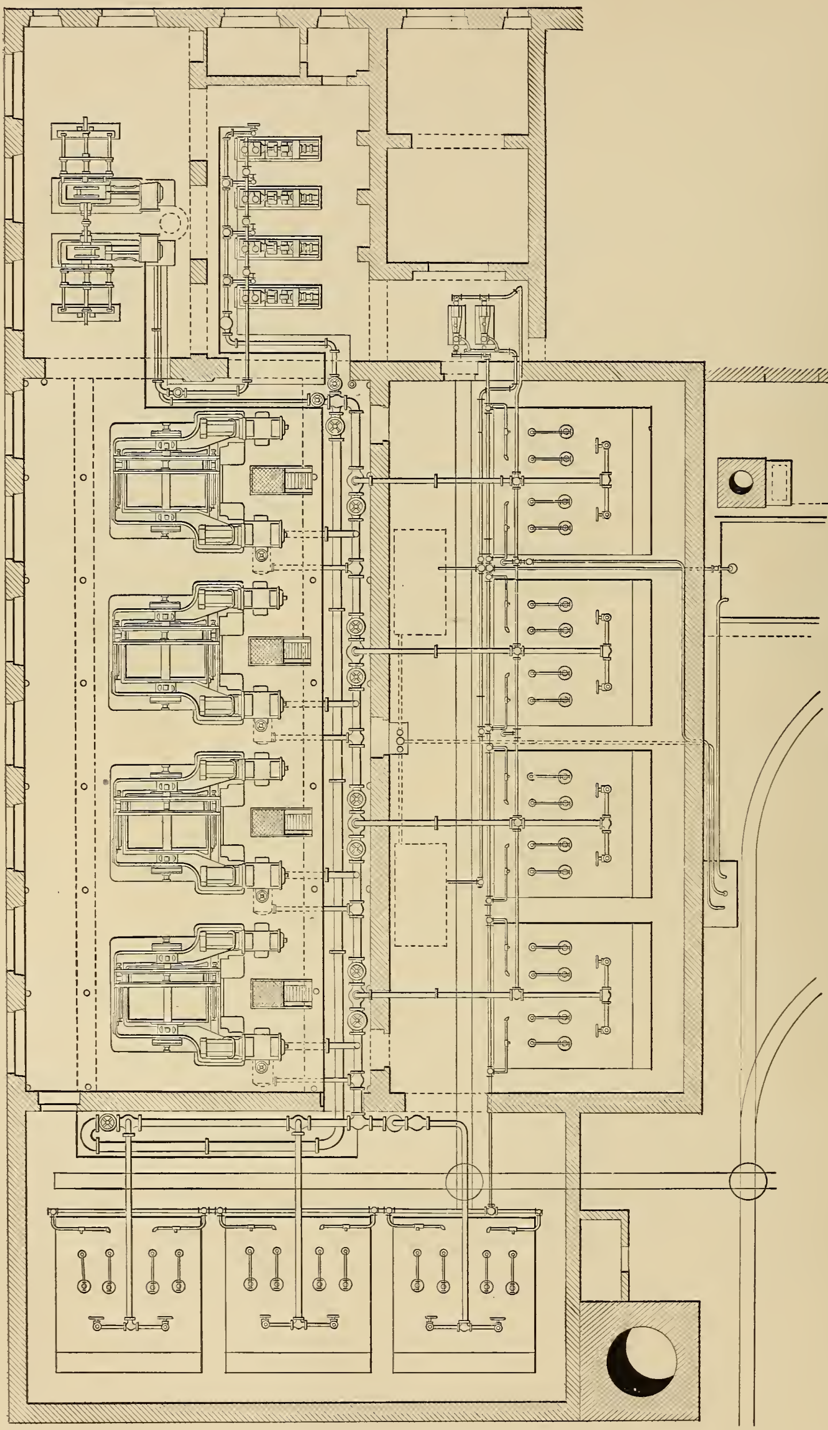


FIG 2.—A PLAN OF THE STEAM CENTRAL STATION AT CERCHI, ROME

the works was executed in all details for the Anglo-Roman Gas Company by Messrs. Ganz & Co., of Budapest, chiefly in accordance with the plans of Mr. O. T. Bláthy, and under the direction of Prof. G. Mengarini.

The central station of Cerchi is very noticeable from a historical point of view, for the plans for it were prepared as early as 1885,—that is, at a time when alternating currents were employed only for small, isolated plants, and not for distribution over relatively large areas. The station was completed in 1889, and entirely on the lines of the original lay-out.

Steam is produced at 120 pounds pressure in fourteen Babcock & Wilcox boilers. As shown in the plan, Fig. 2, the boilers are situated in two rooms forming an ell. As the plant belongs to the Anglo-Roman Gas Company, the boilers are fired only with gas-coke, this being, under the circumstances, a very economical mode of working, especially as the plant is located upon the territory of the gas works and a small Decauville train carries the coke from the gas furnaces directly to the boiler rooms. Feed-water is taken from the river Marrana, and is purified and filtered by Howatson apparatus before use.

O. T. BLÁTHY

The main steam pipe is arranged to form a complete, closed loop, from which the steam pipes leading to the several boilers and steam engines are alternately branched. Each of these branches is between two-stop valves of the main pipe (see Fig. 2), and any one boiler, in case of need, may, therefore, be cut out of the steam circuit and the plant will still continue to work under nearly unchanged conditions, for all the other boilers or remaining steam engines will still be connected in parallel to a continuous main pipe.

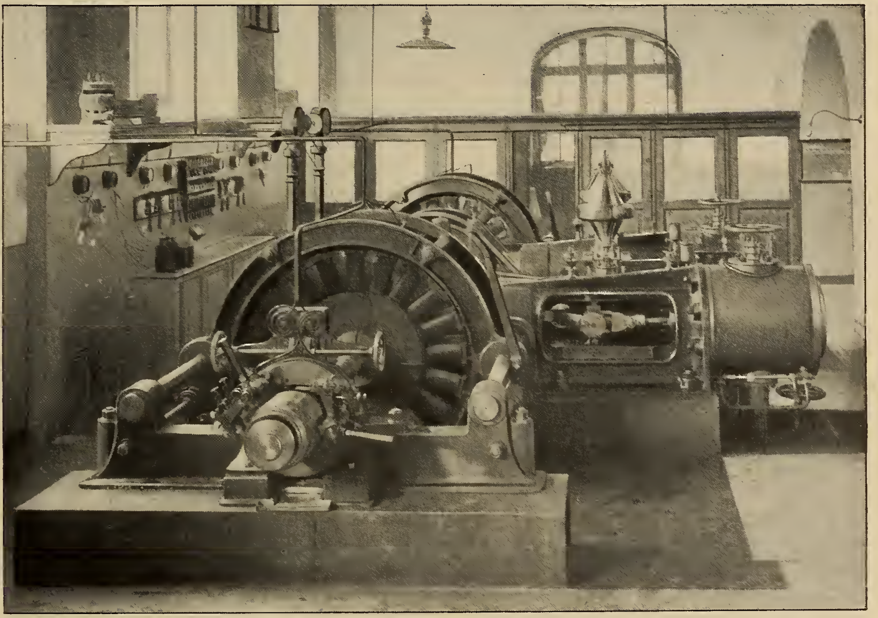


FIG. 3.—THE TWO ORIGINAL GENERATORS AND ENGINES INSTALLED AT ROME IN 1886

The electrical part of the plant comprises two steam alternators of 150 H. P. each and four units of 600 H. P.

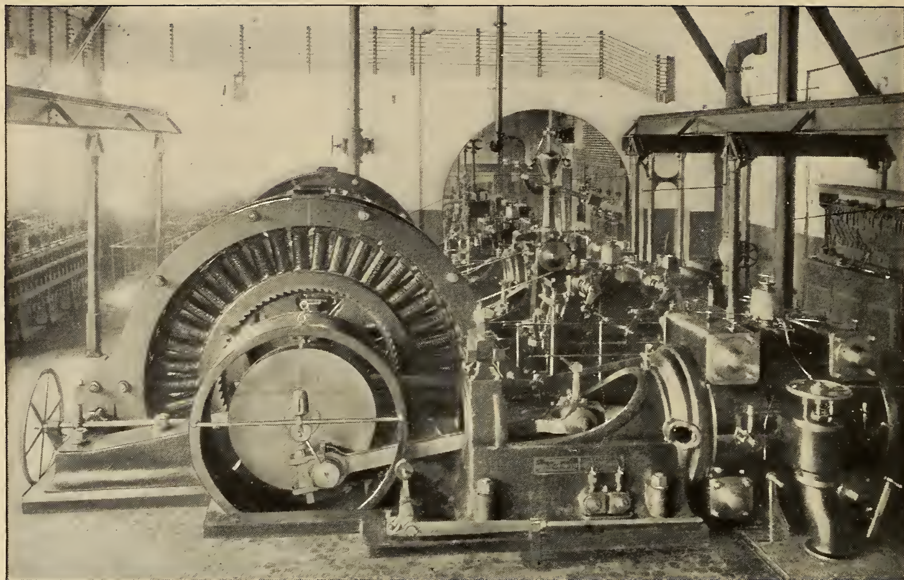


FIG. 4.—ONE OF THE TWO 600 H. P. ALTERNATORS INSTALLED IN 1887

each. The field excitation of these six alternators is provided by four continuous-current dynamos, which, too, are directly coupled to their special steam engines. The first portion of the station, as it was built in 1886, consisted of only the two smaller units with their steam engines. These are illustrated in Fig 3. The two engines have each one cylinder with Rider steam distribution, and were built by Gebrüder Sulzer, at Winterthur, Switzerland. They run at a speed of 250 revolutions per minute, and the cylinders are 15¾ inches in diameter, with a stroke of 17¾ inches. The engines have Porter governors, driven from the engine shaft by belts, and it is worth noting that these are the only belts in use in the whole of the Rome and Tivoli power transmission and distribution plants.

The engines work non-condensing, as condensing water would have been comparatively expensive to obtain, considering the cheapness of the available fuel.

The two alternators driven by these engines have each a revolving field, serving also as a fly-wheel for the engine. The field consists of twenty radial, solid, wrought-iron arms with the field coils slipped upon them, and provided with polar extensions. The stationary armature has twenty coils on the inwardly projecting arms of *T*-shaped cores. Both alternators were at first self-exciting and compounded, which latter disposition is a patent of Messrs. Zipernowsky, Déri & Bláthy, taken out in 1885. Afterwards these machines underwent some modifications and were arranged for separate excitation.

It is an interesting fact that all the alternators which are in use in the Tivoli-Rome plant are of the same design, namely, the so-called "A" type of Messrs. Ganz & Co. It speaks well for the value of a design if the progress of about ten years made but very little alteration necessary in the original plans. These dynamos are exceptionally well suited for high-tension work.

The capacity of the two early alternators is 50 ampères, each at a tension of 2000 volts. As in the year 1885 parallel working of alternators could not be secured with the absolute certainty which is the main condition of regular central station work, a

coupling was provided between the shafts of the two engines. But as soon as self-excitation was abandoned and separate direct-current dynamos were used as exciters, this mechanical coupling proved to be superfluous.

The regular work of lighting Rome began in October, 1886, and the Rome plant was thus probably the very first alternating current central station working at high voltage with an underground distributing system and with parallel coupled transformers.

The plant worked in such a satisfactory way that very soon a considerable enlargement was determined upon. In the second half of the year 1887 two 600 H. P. steam alternators were put in. These units are shown in Fig. 4. The engines, in this case, were built at the well-known works of Van der Kerchove, at Ghent, Belgium, after the plans of Mr. Dantzenberg, engineer of Messrs. Ganz & Co. They are compound, with Corliss valves, and work at 125 revolutions per minute. The diameter of the high-pressure cylinder is 21⅝ inches; diameter of the low-pressure cylinder, 32 inches; stroke, 33½ inches. The alternators coupled with these engines also have revolving fields. The diameter of each field is 9 feet, and it has forty solid wrought iron radial arms with polar projections. Both these alternators worked in parallel during the spring of 1888.

The third and last part of the steam plant at Cerchi consists also of two 600 H. P. units. The engines were furnished this time by the Brünner Maschinenfabriks Actien Gesellschaft. The chief dimensions are nearly the same as those of the preceding two larger units, but some modifications and improvements were made in the design. The alternators are practically identical with the former ones.

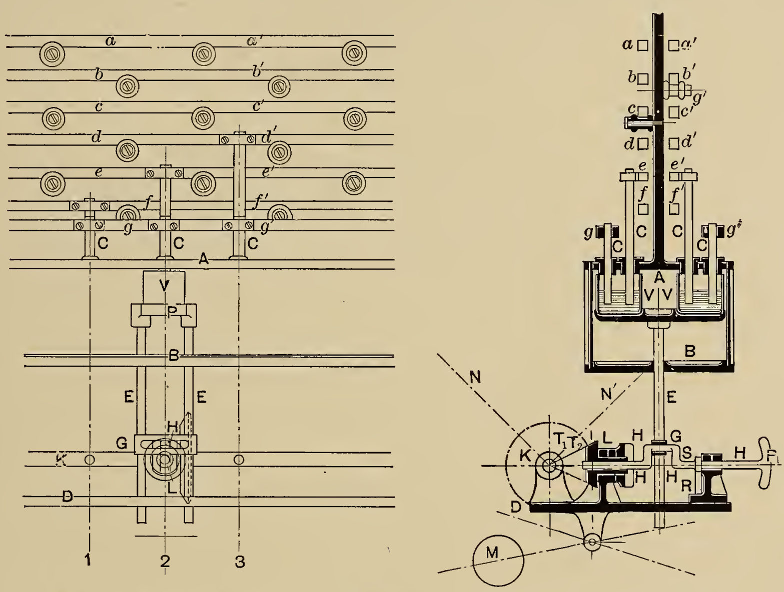


FIG. 5 —ELEVATION AND SECTION OF ONE OF THE CHANGE-OVER SWITCHES

The larger alternators have each a capacity of 2000 volts and 200 ampères. Their field-excitation is provided from four drum-wound four-pole direct-current dynamos. These exciters are coupled directly with their respective steam engines, and give each 150 ampères at 200 volts. Three of the continuous-current dynamos are driven by Westinghouse engines, while the fourth is coupled with a tandem compound engine built by Franco Tosi, of Legnano, Italy. As the current of one ex-

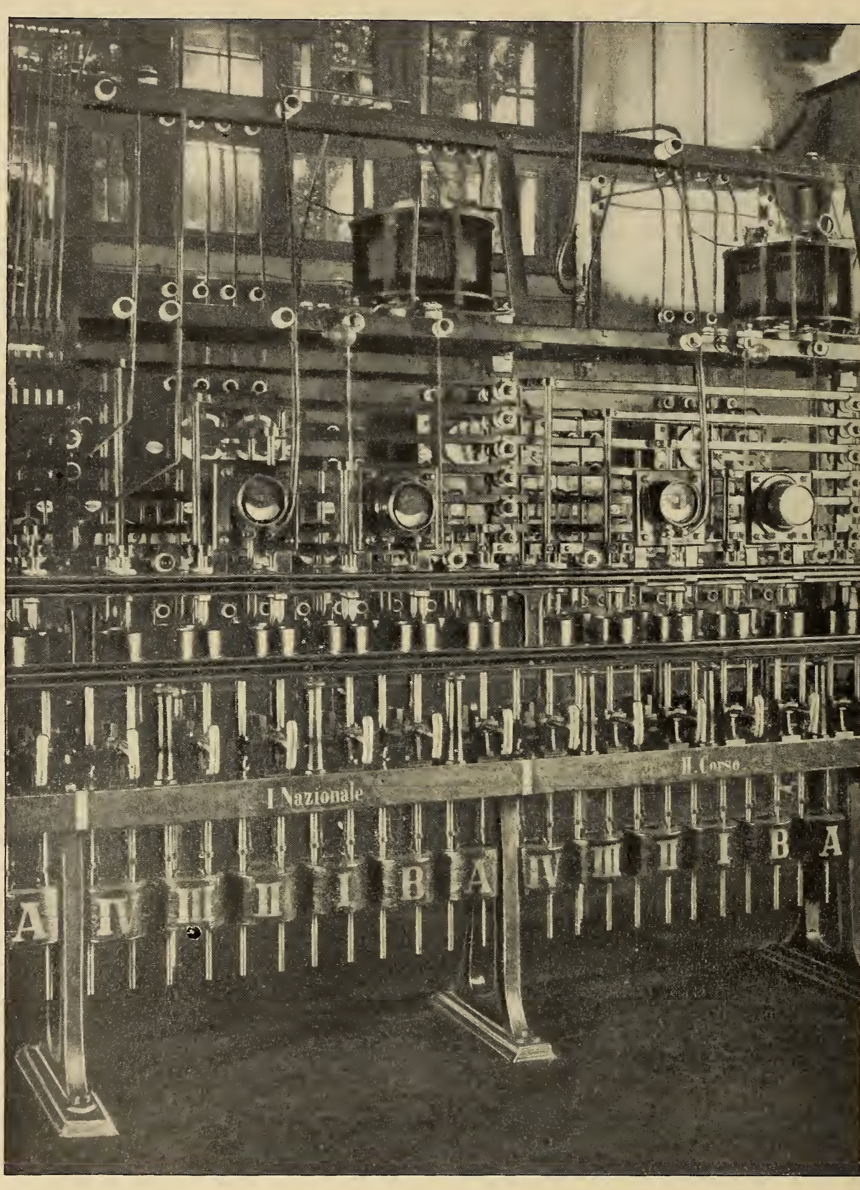


FIG. 6.—THE MERCURY CHANGE-OVER SWITCHES

citer is sufficient for two large alternators, it is evident that the exciter plant is more than ample for its purpose.

As the alternators have to work either in parallel, or if special reasons should make it necessary, independently, four automatic rheostats of the Bláthy type had been provided in order to insure the constancy of the tension. Each of the rheostats may be used for any machine.

The cable net branching from Cerchi consists of four feeder lines, and all these conductors are supplied, according to the temporary current supply, separately or in parallel by the single alternat-

ors. Now it often occurs that either an interchange of the working machines or the exchange of one generator for another one is to be effected without interruption of the work. For this purpose Mr. Bláthy constructed a special change-over switch, enabling any one of the six dynamos to be switched on instantaneously to any one of the four feeders. This change-over switch is of a very ingenious construction, and constitutes one of the features of the Cerchi plant. It is shown in detail in Fig. 5, while Fig. 6 shows a number of them on one of the station switchboards.

The iron frame-work, *A*, supports long insulated copper bars in six horizontal rows. These bars, marked *a* to *f* and *a'* to *f'*, are in electrical connection with the several alternators; thus, *a* and *a'* are connected with the terminals of one alternator; *b* and *b'* with the terminals of a second machine, and so on. The seventh horizontal row consists, on each frame-side, of four shorter copper bars, *g* and *g'*, well insulated from each other and of a combined length equal to the length of the other bars. Two of the bars, as *g* and *g'*, are always connected to the two poles of one feeder, the total number of feeders being four, as will be remembered.

Each horizontal bar has attached to it vertical iron rods; but while the shorter bars connected to the four feeders have six such rods, the longer horizontal conductors each have only four rods, corresponding to the number of feeders. The six rods connected with the bar, *g*, are placed at equal distances, as marked by the figures 1, 2, 3, and so on. Behind each of the rods is situated a longer vertical conductor which is electrically connected to one of the upper six bars. This arrangement is repeated at each bar in the seven rows. The ends of the vertical rods dip into insulated mercury cups, and the mercury thus closes the electric circuit from one pole of the alternator to one pole of a main. Two opposite mercury cups, *v v*, being rigidly held together, it will be seen that in the position shown in Fig. 5 one dynamo will be electrically connected to one of the mains. If we intend to break the circuit, we have only to lower the mercury cups, and this can be done in a manner to be presently described.

It can thus be seen that, with a convenient number of rods and mercury cups, it will be possible to make any desirable combination between alternators and single mains; thus in the Cerchi central station we shall need six mercury cups for each short bar, *g g'*; that is, $4 \times 6 = 24$ cups on each side of the framework, and, altogether, 48 cups for both alternator poles.

The already mentioned cable, carrying the Tivoli current from the Porta Pia transformer station to Cerchi, can be combined with any one of the Cerchi branches by using a special switch which connects the cable with two rods of the change-over apparatus. In this case the corresponding steam dynamo is cut off from these horizontal bars.

The mechanism for raising or lowering the mercury cups is shown in Fig. 5. The mercury table with the two mercury cups *v v*, is supported by the vertical rods *E*, having a horizontal slot, *G*. By turning the crank *H*, the mercury table will acquire a vertical movement, as the crank can slide horizontally in the slotted piece *G*. In the meantime, the shaft *H* on the left enters the bevel wheel T_2, in which it can freely turn.

A shaft, *K*, runs along the whole left side of the framework and carries a number of other bevel wheels, T_1, all gearing with T_2. A lever on both ends of *K* can be turned into one of the positions *N N'*, and by moving this lever a certain turning movement will be communicated to the wheels, T_1, and consequently to T_2. With the position shown in Fig. 5, it is certain that the moving of the lever from *N* to *N'* can have no influence upon the mercury cups, as the wheel T_2 will turn freely around the shaft *H*. In this position the mercury tables cannot be raised or lowered.

However, if we push upon the handle *P*, the shaft *H* will slide from the right to the left, and the crank *H* will

FIG. 7.—A DISTANT VIEW OF TIVOLI, SHOWING THE AQUEDUCT AND WATER FALLS

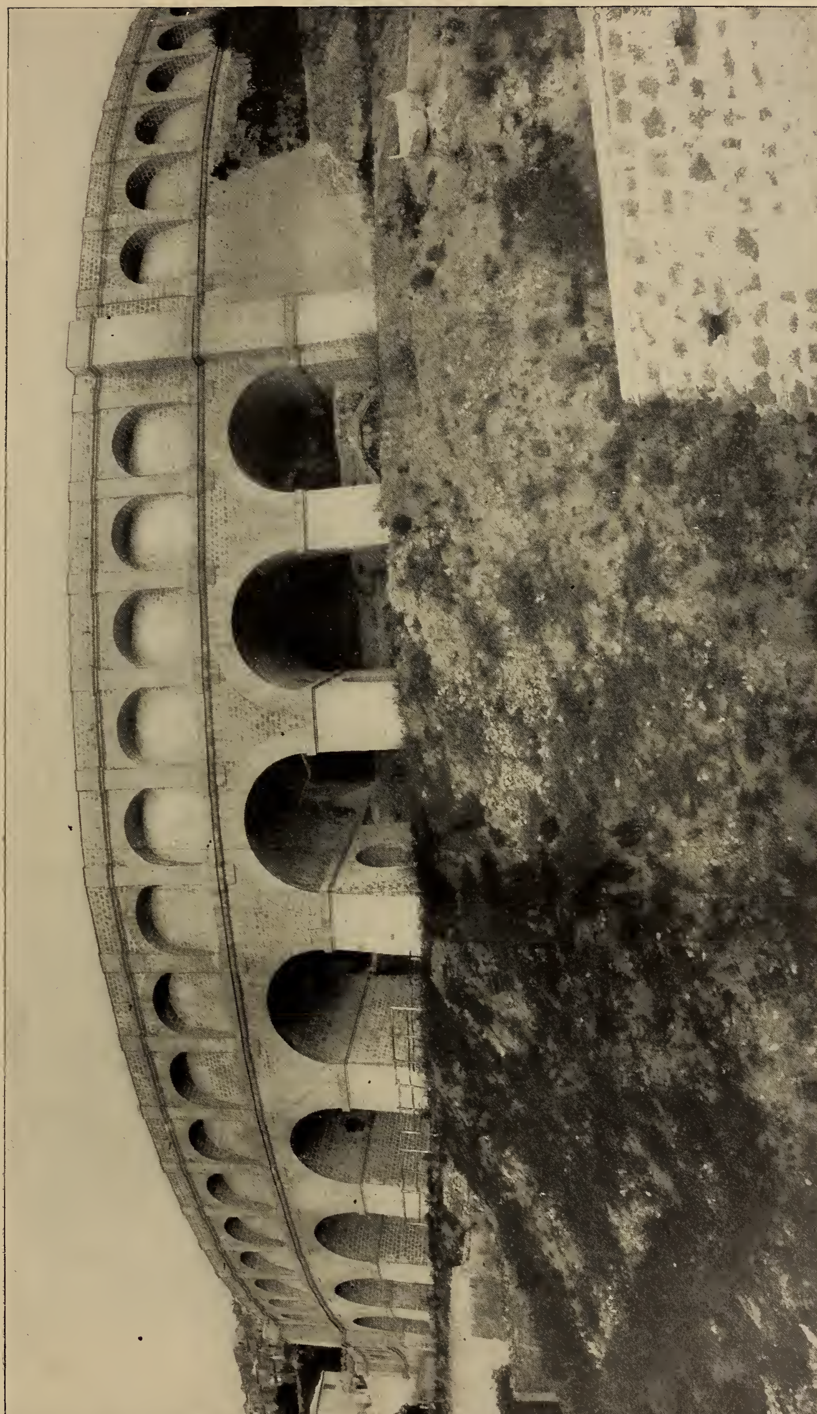


FIG. 8.—A PORTION OF THE GREAT TIVOLI AQUEDUCT

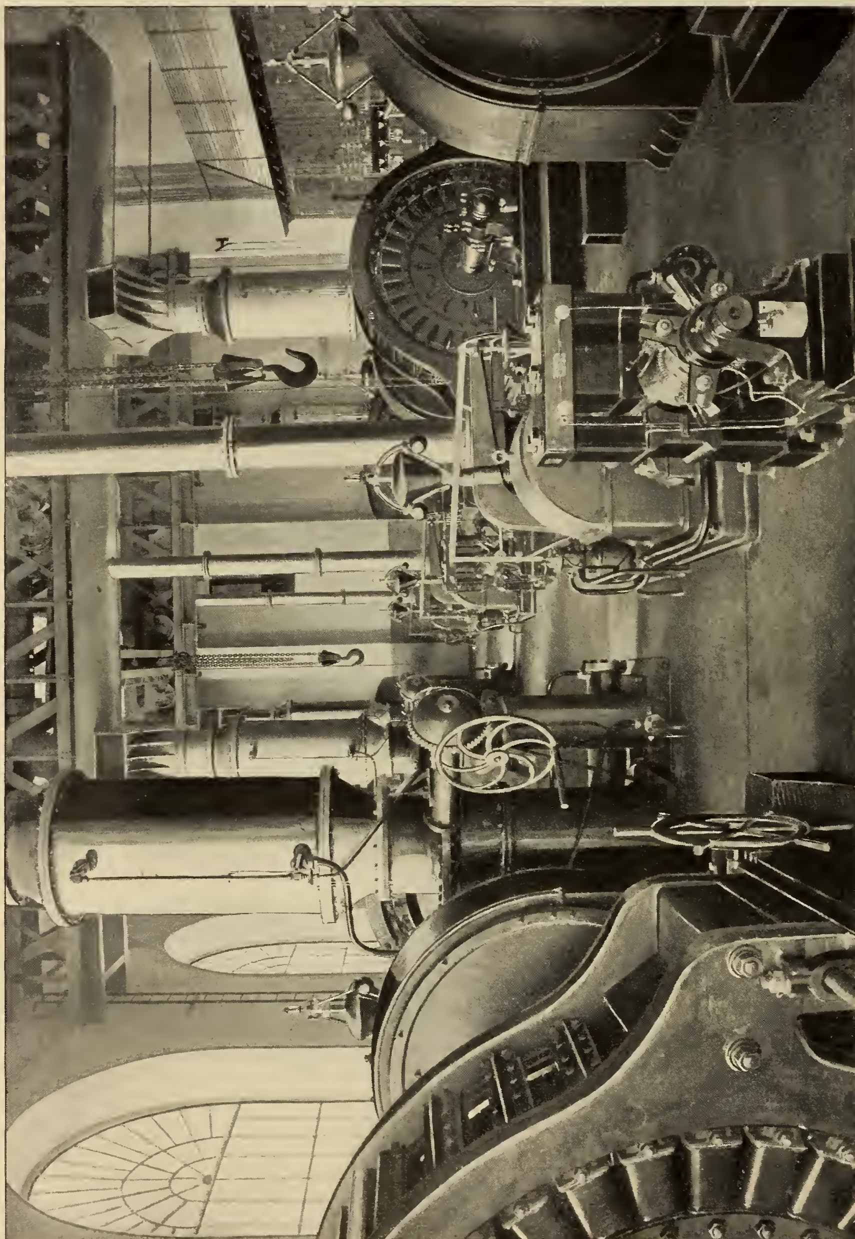


FIG. 9—THE GENERATOR ROOM AT TIVOLI

enter the slotted piece, which is in rigid connection with T_2. Any turning of the shaft K will then cause a vertical movement of the mercury table, as the shaft H and wheel T_2 are then mechanically connected.

The working of the apparatus is very simple. Let us suppose that a certain number of connections is already made by the apparatus; in this case, the corresponding handles, P, are already pushed in. If we intend to change these connections we have to press upon the handles which correspond to these new connections. Then all the wheels T_2 which correspond to the mercury tables to be raised or lowered, are coupled to the shafts H. If the lever of the main shaft is then moved from N to N', the lower mercury cups will rise, while the upper cups will descend, and the old connections will be interrupted and the desired new ones will be made. The motion of the lever controlling the shaft K is a very short one, and, in consequence, the changes are made so quickly and so perfectly that no wink can be noticed upon the burning lamps of the secondary net.

Notwithstanding the repeated enlargement of the Cerchi station, it continued to prove inadequate for the growing demand for current, and it was due to this fact that the hydraulic power at Tivoli was pressed into service. Tivoli is about 17 miles distant from Rome, and the fame of its waterfalls dates far back in history. Even in the Middle Ages their power served for smaller industrial purposes and a number of oil mills of primitive form were worked by them to produce the world-renowned Tivoli olive oil.

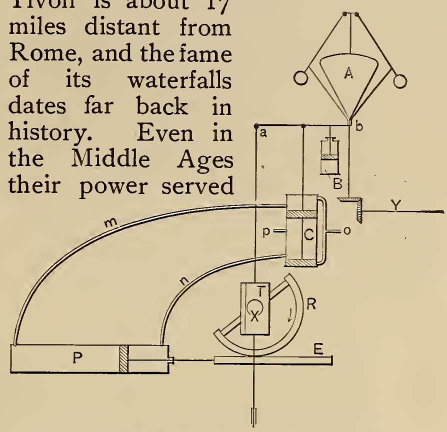


FIG. 10.—A TURBINE GOVERNOR DETAIL

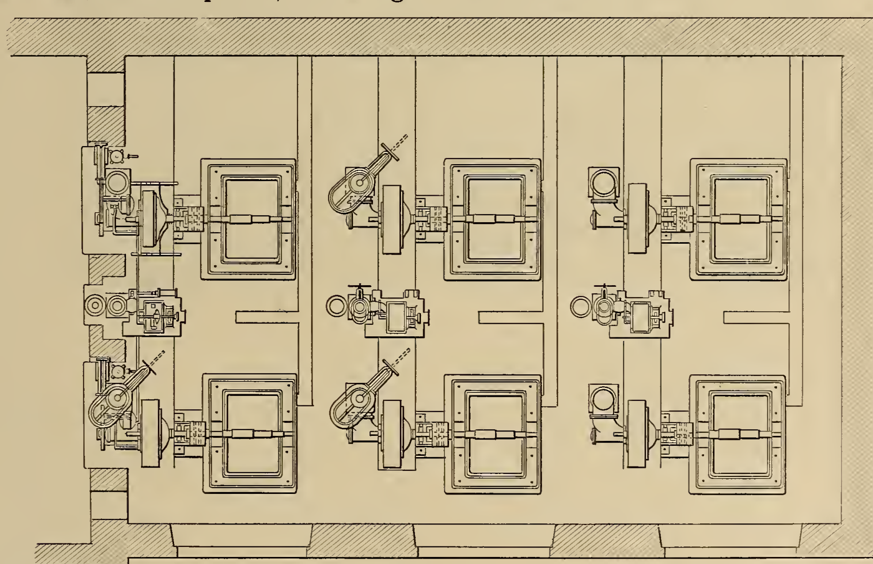


FIG. 11.—A PLAN OF THE HYDRAULIC POWER HOUSE AT TIVOLI

In the year 1887 a small alternating-current electric lighting plant was erected at Tivoli, and this is still in service for lighting the town. In the same year the "Società delle Forze

Idrauliche" was authorised by the Italian government to industrially develop the water-powers. This company intended to utilise them for local industrial purposes, and, besides the irrigation of the near Campagna Romana, proposed also electric power transmission to Rome. Considerable work was done toward this end, but the company for various reasons, could not handle the project in its full magnitude.

In the meantime, the enlargement of the existing Roman central station was urgently required, and the energetic manager of the gas company, Mr. Charles Pouchain, decided to erect, as a beginning, a plant for transmitting 2000 H. P. from Tivoli to Rome.

An agreement was accordingly made between the Anglo-Roman Gas Company and the managers and engineers of the "Società delle Forze Idrauliche," Messrs. Vittorio Cantoni, Raffaële Canevari, Carlo Esterle, for the utilisation of the hydraulic works already built at Tivoli to drive a new large electric plant, having about the contemplated capacity. The next step was the planning and the rapid execution of the actual plant in connection with Messrs. Ganz & Co., of Budapest.

The plant was started in July, 1892, and has been working continuously since that date without the slightest disturbance.

One part of the current coming from Tivoli is used in Rome for the day supply of light and motive power; the other, through the use of rotary converters, and a storage battery system, is employed for operating the tramways as already mentioned. The rotary converters work always at a constant load, for at the times when the demand for power is larger than the total output of the Tivoli station, the deficiency is made up by the storage batteries. Conversely, when a small number of tramcars is running, the current supply for lighting and power will be smaller than the available Tivoli supply, and the latter is, therefore, disposed of in charging the storage batteries.

At night, however, the Tivoli plant alone is not sufficient for private consumers and street illumination, and the Cerchi plant is, therefore, then started, and the storage batteries at the time provide for the whole tramway current requirements. The demand for current diminishes after midnight and then the steam plant is shut down. Besides, no

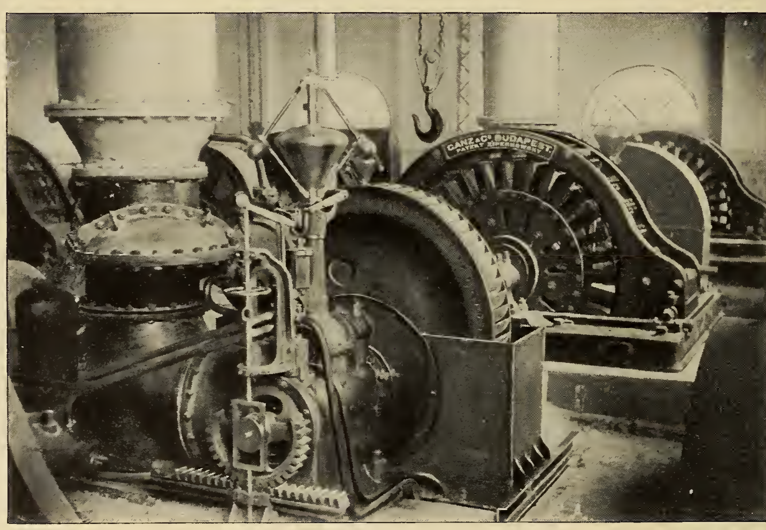
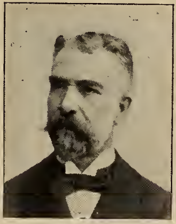


FIG. 12.—ONE OF THE TURBINES AND GOVERNORS

tramcars run after that hour, and the greater part of the Tivoli current can then be again employed to charge the storage batteries.

The hydraulic plant in this way works under the most favourable conditions possible, namely, under a full load. On the contrary, the steam plant, of which the working expenses depend considerably upon the working time, is not running except during a few hours of the evening, when the current consumption is at a maximum.

The great Tivoli aqueduct, as previously intimated, was built by the "Società delle Forze Idrauliche," and has a capacity of about 425 cubic feet of water per second. A smaller conduit, of about 140 cubic feet capacity, branches from this main channel, and is used for driving the electrical plant. This branch also supplies several factories in Tivoli, and the water is, therefore, screened before flowing to the lighting plant. Moreover, a tank, of about 35,000 cubic feet capacity, is here provided in order to purify the water required for the running of the turbine regulators. An iron pipe, which runs along the ancient country residence of Maecenas, conveys the water from the just mentioned purifying apparatus to two factories; then only, after having done useful work there, it runs along the arcades shown in the illustration opposite the opening page of this article, down to the corner turret above the main building of the electrical plant. By means of gates which are inserted on this part of the channel the water can be conveniently shut off from the central station, and the water which is then not required to generate electric power will rush down to the river below between two brick walls erected near the waterfall visible in the illustration. In this way spray from the water-fall is prevented from reaching the plant, for it would be disastrous to the insulation of the high-tension alternators.



CHARLES POUCHAIN

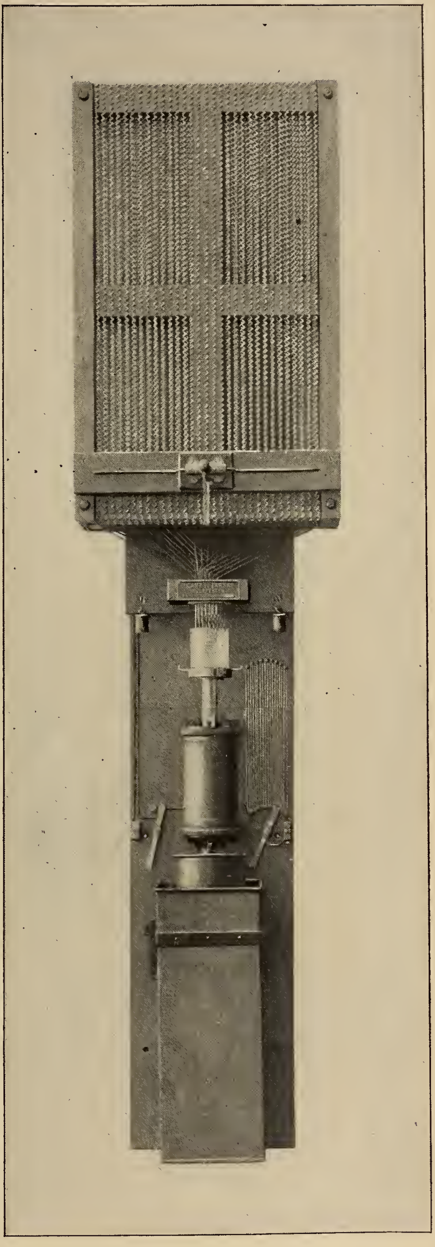


FIG. 13.—A BLÁTHY AUTOMATIC RHEOSTAT

With the plant at work, the water, flowing along the arcades, is carried to the central station through an iron conduit in the already-mentioned corner

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turret. This vertical conduit has a funnel-like opening on its upper end into which the water pours. At the lower end it is joined to a second pipe, about 5 feet in diameter, which leads horizontally to the dynamo room, about 100 feet off. As this pipe is parallel with the longer side of the building three smaller pipes branch from it and enter the dynamo room at the height of the roof. Each of these pipes supplies water to three turbines, forming one distinct group. Consequently, three vertical conduits descend from each one of the three horizontal conduits, and there are thus,

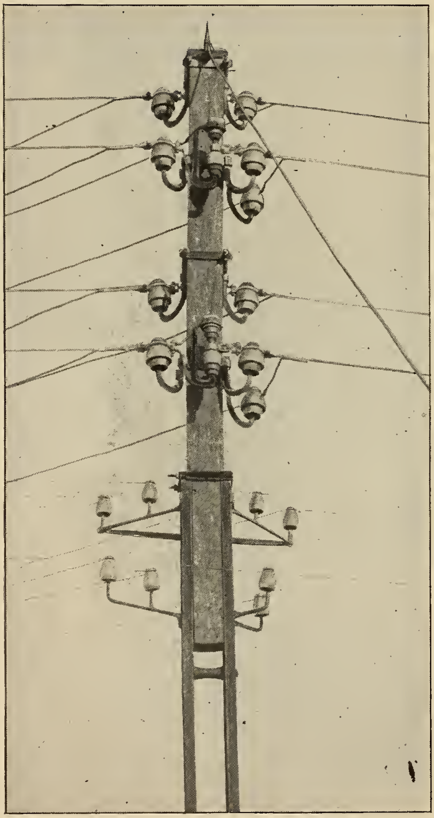


FIG. 14.—THE POLE AT THE HALF WAY STATION

altogether, nine vertical columns, serving as many turbines. Each group consists of two larger turbines, coupled directly with their alternators, and between them there is a smaller one which drives the direct-current exciter dynamo.

The available head of water is about 360 feet, but is not fully utilised. Fig. 9 shows that the electrical plant is high above the River Anio, into which the waste water is discharged. As the plant is about 165 feet below the upper water conduit, only about 2000 H. P. is available.

Stop-valves are provided in the vertical feeder pipe of every turbine. These valves, which are arranged to be operated by hydraulic pressure, were designed by Mr. Wein, of Messrs. Ganz & Co., and the simple turning of a cock is sufficient to operate them. The operating mechanism consists of a cylinder, with piston and rod, to which the turning of a cock, through proper water connections, admits water under pressure, and this, in turn, forces the piston forward or backward, as the case may be. The rod directly controls the motion of the stop-valve, and the flow of water in the conduit is thus easily governed. Moreover, the special construction adopted permits the apparatus to be worked by hand in cases of emergency instead of by hydraulic pressure. The turbines are all of the well-known Girard type, with horizontal shafts.

The speed regulating mechanism, shown in Fig. 10, and designed by Mr. Bláthy, comprises the governor A (which is put in motion by the turbine shaft Y), the cataract cylinder B, the slide valve C, and the pressure cylinder P. The turbine gate is controlled by the shaft X, which carries two cog-wheels. The smaller one gears with the toothed frame T, and the larger one R, meshes with the rack E, which is virtually a prolongation of the piston rod of the pressure cylinder P. The slide valve C has four pipe connections ; two of these, m and n, go to the pressure cylinder below, while p carries the full hydraulic pressure, and o is used for exhaust.

Let us assume now that the speed of the turbine is suddenly decreased! The governor weights will descend; consequently the horizontal rod ab, will turn about the point a, and both pistons of the slide valve C will move down-

FIG. 15.—THE HALF-WAY STATION BETWEEN TIVOLI AND ROME

wards. The pipe p will be then connected with n, causing the piston P and rack E to move to the left. In the meantime, the gear R, and axle X, are turned by E, and the turbine gate will thus be opened farther, tending to increase this speed. But the turning of the shaft X acts, of course, upon the toothed frame T, and shifts it upwards. The horizontal rod ab will turn again, but this time around the point b, and consequently the slidevalve C will be returned to its initial position.

The speed governor requires very clear water for thoroughly good working; otherwise, stoppages of the pipes would be likely to occur. Purifying of the water is done in the previously mentioned tank, in which the mechanical impurities are deposited. The larger turbines have a rated output of 350 H. P. at 170 revolutions per minute; the smaller ones develop 50 H. P. at 375 revolutions.

The alternators, which are coupled directly to the turbines, are of the same

FIG. 16.—THE TRANSMISSION LINE

construction as the dynamos of the steam plant, namely, with stationary

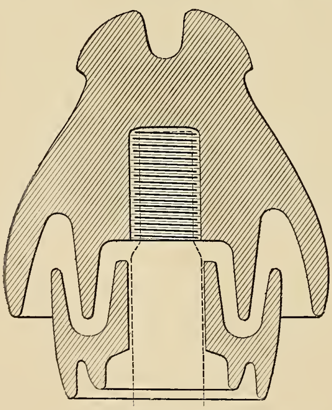


FIG. 17.—CROSS SECTION OF ONE OF THE INSULATORS

armature and revolving field-magnets. The chief data of these alternators are:—

Number of revs. p. m. at full load	170
Maximum voltage corresponding to 170 revs.	6000
Ampères at full load	72
Number of poles	30
Diameter of the revolving field (feet)	7.2
Weight of the alternator (tons)	12
Efficiency, exciting included, per cent	92

The direct-current dynamos are four-pole machines, with drum-wound armature, giving 150 ampères at 200 volts and 375 revolutions per minute.

The conductors which connect the switchboard with the several alternators are put into small trenches underneath the floor.

The switchboard has a total length of 67 feet and a height of 12.5 feet, and is arranged along one side of the generator room, parallel with the turbine-dynamo axes. It contains all the apparatus to control the running of the electric plant, and is, moreover, arranged so as to permit parallel working of the alternators as well as the parallel coupling of the direct-current exciters.

Parallel working at the Tivoli plant can be effected by first loading the machine to be connected in parallel with a variable resistance to the same degree as the other machine which is already working. A voltmeter shows when the generators are in phase, at which time the coupling switch is thrown. Afterwards the loading re-

sistances are to be withdrawn by degrees from the main circuits. However, the parallel coupling is made generally in a simpler way by the regulation of the water admission.

The switches used on the switchboard for high-tension work are all mercury apparatus. They have very great advantages, and their manipulation is very easy and without danger; they have been constructed also for larger current intensities. The switch shown in Fig. 18 has four contact pieces provided with long bars. The two mercury cups are thoroughly insulated and can slide in a vertical direction ; raising them by the lever shown below causes the bars to dip into the mercury and close the circuit.

The constancy of voltage for alternators and exciters is easily maintained by automatic rheostats of the Bláthy type, shown in Fig. 13. This apparatus consists of a wooden frame carrying wire resistances. These terminate in ends which form a sloping surface and dip into a basin of mercury. The basin has an automatic vertical movement in both directions, depending on the terminal pressure of the machine. When the basin reaches its highest position, each wire end dips into the mercury and all the resistance is short-circuited; in its lowest position, the wires are drawn out from the mercury and all the resistance is inserted. In any other position there is always a correspondingly varying number of wire ends dipping in the mercury.

The basin is fixed to a vertical tube carrying a piece of iron in its interior; at its bottom it is screwed to a float-gauge dipping into a water tank at the bottom of the apparatus. The action of the float-gauge is upward; just the reverse action is produced by a special bobbin placed around the iron core. This latter action is, of course, a magnetic one. There are regulating weights attached to the moving part, and they are chosen in such a way that, admitting a certain determined current to the bobbin, the iron core should be well balanced in each position. If this current be changed, the iron core will shift its position till the regular and normal conditions are re-established.

At Tivoli this apparatus cannot be used simply in the way described here. In electrical plants supplying distributing centres at very great distances the tension at the terminals of the dynamo is to be varied in order to have a constant tension at the junction of the feeders and of the distributing net. It would have been possible to conduct two wires from this junction point to a voltmeter in the central plant and to

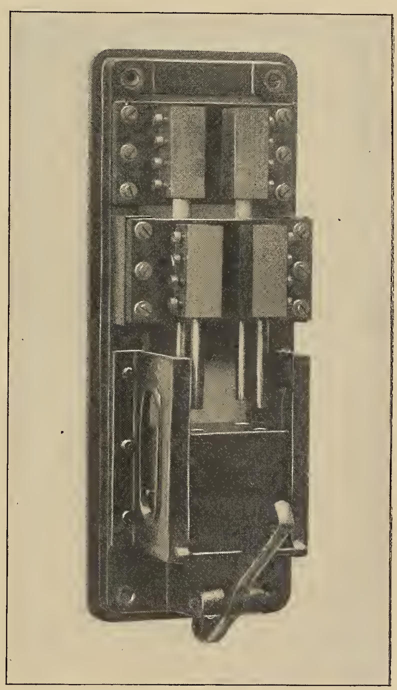


FIG. 18.—ONE OF THE MERCURY SWITCHES

vary the excitation of the alternator corresponding to the indications of this apparatus.

However, Mr. Bláthy, in 1886, designed a method permitting the tension to be kept automatically constant at the Porta Pia transformer station, even if the load varies considerably. He uses two transformers in connection with the automatic rheostat described above; one of these transformers is shunted in, and the other is in series with the mains. It is evident that the second-

FIG. 19.—A VIEW IN THE TRANSFORMER STATION

ary tension of the series transformer will vary in the same manner with the current intensity in the primary, as the voltage drop in the line, while the secondary terminals of the shunt transformer have a varying tension, which corresponds to the varying tension of the central plant. By using suitable resistances the free terminals of both secondary windings in series will give exactly the voltage which is at the junction point of Porta Pia, and may be, therefore, connected directly to the magnetising bobbin of the automatic rheostat.

The direction of the power-transmission line had been practically prescribed by the previous location of the water conduit connecting Tivoli and Rome, through the Campagna Romana. Both electrical and hydraulical lines run along together for nearly two-thirds of the whole way. Beginning at the central station, the line descends to, and passes over, the River Anio, which flows below the station at a depth of about 165 feet, rises up on a hill beyond, and traverses a large plantation of olive-trees, till it meets the Marcia water conduit.

Both lines then go side by side towards Rome up to some distance before Ponte Mammolo (a bridge over the Anio). There the lines diverge, the electric line taking a shorter cut to Rome. At different points it crosses the railways of Rome-Sulmona and Rome-Orte and the government telegraph lines. At these several crossing places safety apparatus was erected to prevent any possible damage and danger from the breaking down of a high-tension wire. Along the whole line a strip of land, 9 feet wide, has been acquired by the Anglo-Roman Gas Company, thus providing for the erection of a second pole line whenever the already projected further enlargement will be carried out.

Half-way between Tivoli and Rome there is a small house, called the "Capanacce" (Fig. 15). It is not only a dwelling for the line guard, but it is used also as a depot for repair tools

and material. Electric measurements also may be conducted at this point. Accordingly, the pole nearest to the house, shown in Fig. 14, is provided with sectional insulators, interrupting the continuous line from Tivoli to Rome. The several wires enter the upper part of the tower-like structure through a special window and connect with mercury switches of the type previously described. In the same room are the lightning arresters, while telephone and telegraph instruments are in a room on the first floor.

One form of pole used consists of two *I* beams about 29 feet high. Special cast iron distance pieces are inserted between both beams, which are bolted together. An iron foot is provided on the lower end, and the pole is set into a cement foundation 6½ feet deep. At the upper part there is a wooden beam 5 inches square. This extends upward for about 9 feet, and upon it are mounted four sets of brackets which support the porcelain insulators. The smaller insulators below, which are bolted to the iron beams, serve for telegraph and telephone purposes. A lattice-work pole is also used on some parts of the line as shown in Fig. 21

All the insulators used were designed by Prof. Mengarini, and were furnished by the Ginori Works, at Folence. One of the high-tension insulators is shown in section in Fig. 17. It has two rims, the interior one dipping into a porcelain vessel which is filled with mineral oil. The oil does not appreciably increase the insulation of the line, but simply keeps it constant by preventing insects from building their nests in the interior of the insulator. This precaution was demanded by the special climatic circumstances of the Campagna Romana, and proved to be efficient during the period of a little over five years that the Tivoli-Rome line has been continuously in service,—a comparatively long time in the short history of the electric high-tension power distributions.

The insulator support ends in a form of stirrup-iron, clamped around the wooden top of the pole. The frame visible in Fig. 16, which incloses each insulator, is made of strong iron wire. It prevents the line wire from falling down if either of the connections should become loosened or the insulator break or become detached from its support.

Each pole is covered with lead on its top and carries a bundle of copper points which communicate with the iron structure forming the pole proper. This serves as a lightning conductor.

As mentioned above, the telephone and telegraph lines are fixed directly to the iron part of the pole. Phosphor-bronze wire is used for both the main and return circuits. In order to avoid the influence of induction, which, as alternating currents are used, would be disastrous to the telephone service, the wires are alternated at every tenth pole, or, thus, every 1500 feet. The absolute potential of the telephone line with regard to the earth is very high, so that a person touching it and being in contact with the earth (or the pole) gets a very sensible and disagreeable shock. In this way the telephone and telegraph wires, located under the four high-ten-

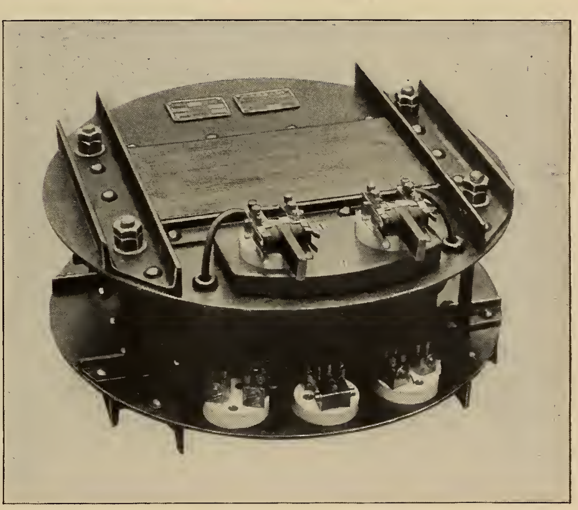


FIG. 20—ONE OF THE GANZ TRANSFORMERS

sion wires, form an effective guard against coming in contact with the dangerous high-tension conduit.

There are four small stations along the line which are provided with a telephone, so that the line guard is able to readily communicate with the terminal stations.

The extreme height of a pole when erected is about 31 feet, and the lowest high-tension wire is a little over 24 feet above the ground. The wires themselves are 4 feet apart, vertically. The distance between two poles is 150 feet, except when the line crosses the River Anio or the railway tracks. At those points the distance is somewhat greater. Altogether, 707 poles are used.

The sectional area of the conducting copper cable is 0.161 square inch, and it consists of 19 wires, each of 102 mils diameter. A long series of careful tests were made with the copper to be used before deciding upon its availability. Finally the order was given to the Metallurgic Society, of Livorno.

The insulators are cleaned every two years, and then the mineral oil also is renewed, and at the same time the poles are newly painted. Fig. 16 will give a very good idea of the general character of the power transmission line.

The high-tension current coming from Tivoli is conducted to the transformer station of the Porta Pia. Here the Tivoli current is transformed for the supply of public and private lighting, and also for the tramway supply. Fig. 21 represents a view of the station, which comprises two rooms, one containing 832 transformers, each of 30 kilowatts capacity, while the other contains the switchboards, controlling apparatus, and automatic rheostats.

The transformers are shown in Figs. 19 and 20. They are of the latest Ganz type, and have their iron cores made of two parts. Each part consists of *E*-shaped iron pieces, held together by two end pieces. These are circular, and have a diameter so large that the transformer can be rolled on the floor, which circumstance greatly facilitates their handling. One of the shields carries the primary and secondary terminals. Each current conductor is supplied with its separate fuse mounted upon the wall of the transformer room, and can be exchanged even during regular work, as they are provided with long wooden handles.

The thirty-two transformers are divided in two batteries, of sixteen each.

FIG. 21.—THE TRANSFORMER STATION AT PORTO PIA

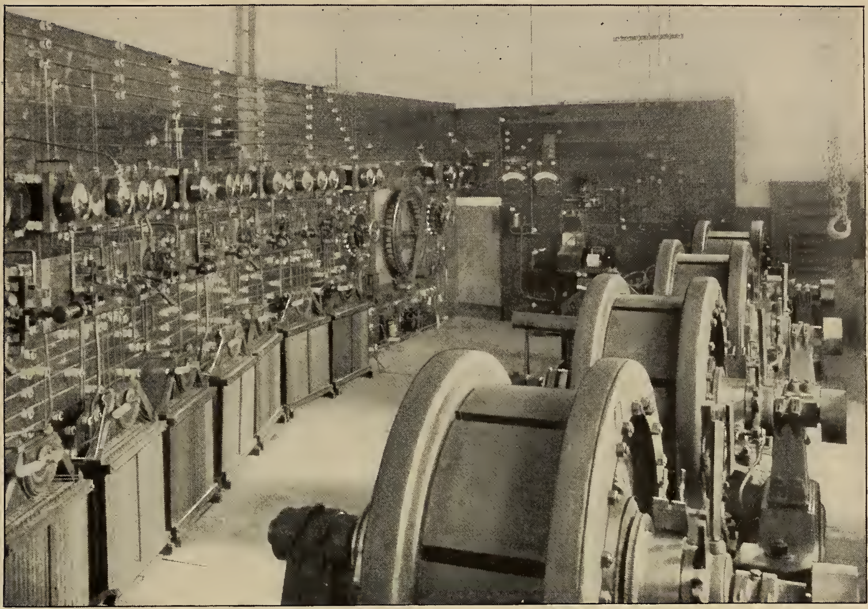


FIG. 22.—THE FIRST CONVERTER PLANT

One battery is used for private supply and the other for public lighting.

The secondary terminals for the private supply are connected in parallel to the secondary main bars. On the special private supply switchboard there is a mercury switch in the circuit of the main bus bar. Two ammeters, one in each bar, also are installed for measuring the current flowing into the distributing system. One of the secondary main bars runs along the whole length of the switchboard, but has four branches at equidistant points which are provided with mercury switches. The second main rod branches into four parallel copper bars, and each of these conductors has a recording wattmeter, a small switch and an ammeter, terminating finally at one of the mercury switches on the other four branches. These four mercury switches control the four underground feeders for the private lighting supply.

The second lot of the transformers, containing also sixteen units, serves for the public lighting, which is done by arc-lamps connected in series. There are 227 lamps in use; but as the number of the burning arcs is variable, the tension on the transformer terminals must vary accordingly. The secondary winding of each transformer is, therefore, divided into four equal parts,—that is, each part has an equal number of turns. The transformers are designed to give 2000 volts, and the difference of potential between the terminals of each section is, therefore, 500 volts. Accordingly, if, say, twelve arc lights are in the circuit, only one section is used; when twenty-four arcs are burning, two sections will be used, and so on. The maximum number of arcs in any circuit is 50. An automatic rheostat of the Bláthy type is inserted in each arc circuit, and by the automatic increasing or diminishing of its resistances the current intensity is kept constant.

The series arc circuits are composed of concentric Siemens cables, and each of these is supplied directly with current from one transformer. Though there are twelve circuits, only six are actually at work.

The arc-lamps in the streets are from 130 to 160 feet apart and 25 to 30 feet

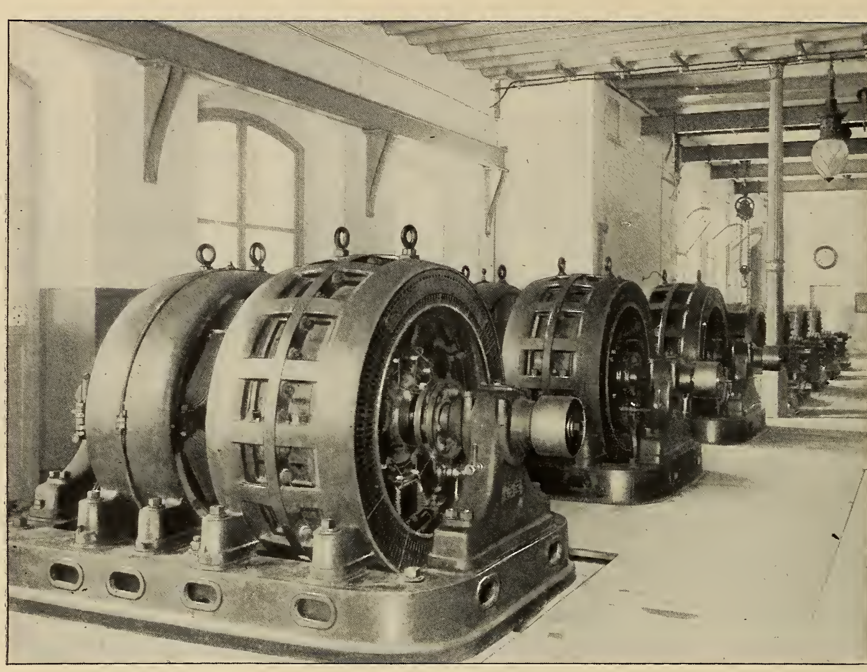


FIG. 23.—THE SECOND CONVERTER PLANT

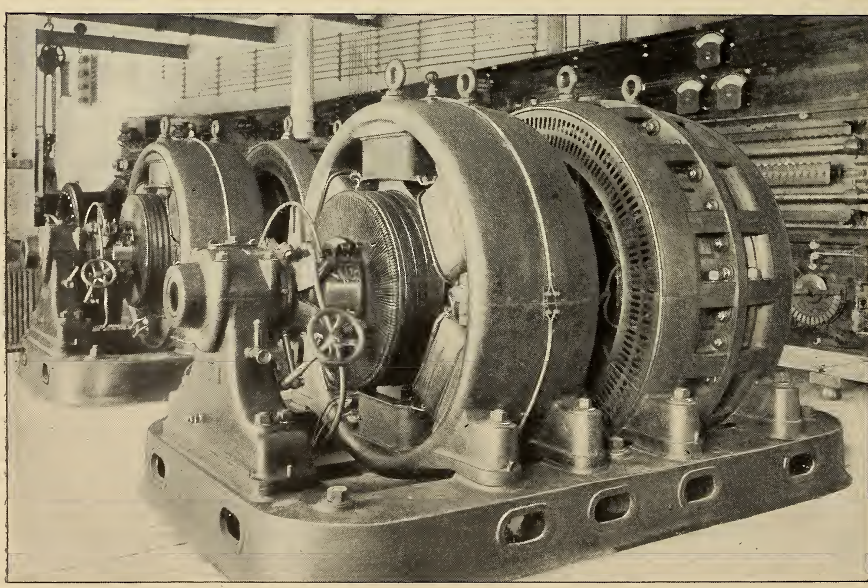


FIG. 24.—ANOTHER VIEW

above the ground. Each lamp takes 14 ampères at about 35 volts. They are all of the Zipernowsky type, and will burn 14 hours without requiring a change of carbons.

Four independent concentric cables branch out from Porta Pia for private light and power consumers. The distribution is effected, as previously mentioned, at a pressure of 2000 volts. The consumers using 102-volt incandescent lamps and 51 volts for parallel arcs are supplied with a current reduced in tension by transformers placed all along the underground mains. These transformers are of the same construction as those in the Porta Pia station, and have, throughout the system, a constant ratio of transformation, namely, 1 to 18.

The distribution of the secondary current in alternating current central plants is generally effected either with a high-tension primary system and with house transformers, or with a secondary low-tension distribution system (like the continuous-current system) which is connected with transformers, grouped in substations and disposed at suitable distances from one another.

The method of the house transformers has the disadvantage that the transformers may never, or rarely, work at full load, and the cost of maintenance and operation is relatively very high. The second method of having a secondary low-tension system gives better economy from both points of view, but as an offset. entails greater expense for the distributing mains, and may cause disagreeable disturbances in the service if it should be attempted to secure extreme economy in the number or output of the transformer substations in order to have a constant full load on them.

This latter method of distribution was formerly employed in Rome. Nevertheless, after a very extensive and thorough experiment of several months with this system, Prof. Mengarini came to the conclusion that the preferable method of distribution was to erect a certain number of secondary substations in such a way that every secondary net is quite independent and distinct from the other one. It may thus be considered as a mean between both the other methods of distribution. Each station is supplied with the primary current at a tension of 2000 volts, and feeds a little secondary three-wire system having 102 volts between the three wires.

It is a very important problem to find the economical radius to give to a secondary net; that is, the longest distance over which current may be supplied from it at a profit. Considering the cost of the low-tension insulated cables and of their laying, the expenses for the excavations and street pavements, and the expenses necessitated by the small transformer rooms, Prof. Mengarini found the economical radius for Rome to be 410 feet. If, therefore, a new consumer is to be supplied from a secondary net at a distance of less than 410 feet from the substation, he is simply connected to the secondary cables of this station. If the distance is greater than 410 feet, a new secondary station is erected at a distance, approximately, of 820 feet from the nearest substation.

The number of secondary stations in Rome was 148 for 2329 kilowatts at the end of 1896. Each station is provided with a number of transformers corresponding to the power to be distributed. Some have an output of only 10,000 watts, while some others are of 100,000 watts capacity. Fig. 25 shows a portion of a secondary station at the "Piazza Colonna."

Prof. Mengarini is of the opinion that his system gives great economy, both in the expenses for cables and transformers, and in the energy consumed in operating the transformers. Moreover, all the consumers of the city are divided between 148 smaller plants, which are electrically quite independent from one another plant.

When the Roman Gas Company intended to furnish the current for the tramway service a considerable enlargement of the Porta Pia transformer plant was necessary. Twelve new transformers, each of 30 kilowatts capacity, were erected specially for the tramway supply (ratio of transformation, 1 to 10).

Moreover, two large rooms were provided for the rotary converters and two rooms for the storage battery.

When the converter plant was projected, it was necessary to consider the current fluctuations which are unavoidable in tramway operation. With the combination of an alternating-current lighting supply and a direct-current tramway service, two points demanded careful consideration:—

(1) The reaction of the fluctuations upon the lighting system.

(2) The fact that the converters (being synchronous alternating-current motors) would break down when suddenly and too severely overloaded.

A great number of trials were made at the Ganz works in order to eliminate the influence of both circumstances. Finally the parallel working of the converters and of a storage battery was accepted as the best and most economical solution of the problem. The tests were made by Messrs. Bláthy and Prof. Mengarini, in Rome, according to a very ingenious arrangement, patented by Prof. Mengarini, and gave a most satisfactory result. The whole plant has been actually at work for over two years and not the slightest wink has ever been perceived at any burning lamp, nor has any converter broken down from overloading. Both facts are well worth noting, especially as the Roman tramcars are generally well loaded, and there are many heavy grades.

The first converter plant was erected in September, 1895. In this the Tivoli current is first reduced to 400 volts, at which pressure it enters the collector rings of the converters. On the other side of the revolving armature direct current is collected from the commutator at a pressure of about 560 volts. Each converter has a capacity of 100 H. P. at 635 revolutions per minute. A view of this plant is given in Fig. 22.

The second plant, erected in November, 1896, consists of four converters,

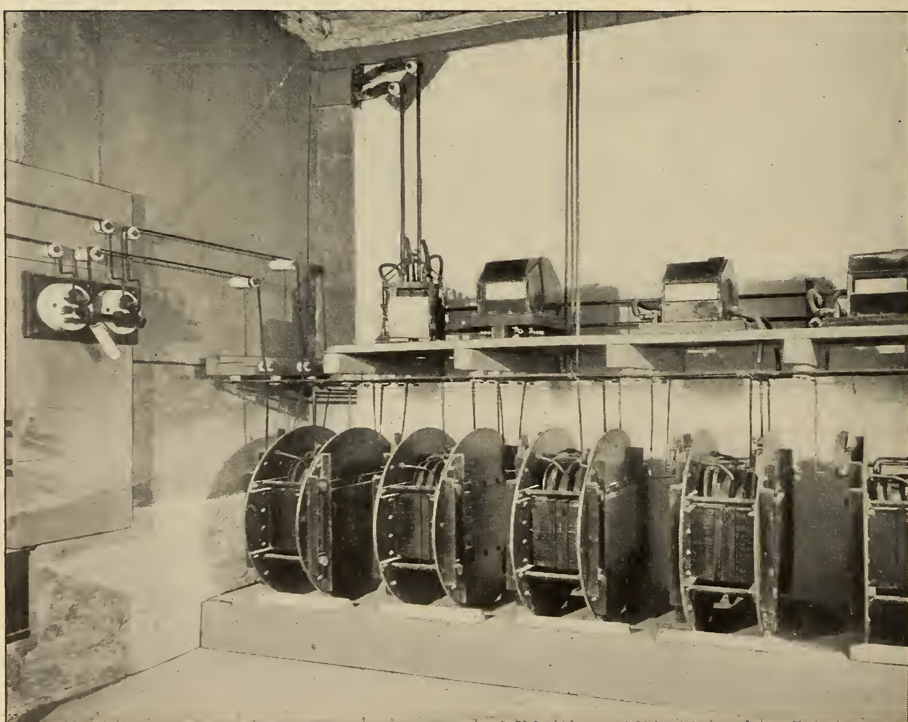


FIG. 25.—ONE OF THE SUB-STATIONS IN ROME

FIG. 26.—THE STORAGE BATTERY PLANT

which are, however, of a different construction. Here the alternating current, coming from Tivoli at a tension of about 4200 volts, is transformed directly to continuous current of 560 volts without the intermediary use of any step-down transformers. The converters, shown in Figs. 23 and 24, consist of two electrically independent parts. Each one is, in reality, an alternating-current synchronous motor, driving a direct-current railway generator. Both machines are bolted to the same bed. The synchronous motor has revolving field magnets supplied with low-tension direct-exciting current by two collector rings. The high tension winding is stationary, and is located in the outer ring of the motor. The whole machine, as a dynamo-motor, has only two external bearings, and the revolving field and continuous-current armature are not separated by any bearing between them. Each of these converters is designed for an output of 200 H. P.

Both converter plants supply current d rectly into the tramway mains and into the parallel working storage batteries. They are operated by starting them by the accumulators, as direct-current motors; when synchronism is reached the stationary winding is connected to the Tivoli conductors.

When the lighting plant is not fully loaded, that is, at daytime till four or five o'clock P. M., the converters supply the tramway motors and the storage battery. The exciting current of the converters and the number of accumulator-cells in series can be changed in such a way that the current supplied by the converter corresponds to the average power consumption of the tramway. This current flows from the converter to the overhead feeders, and, besides, to the storage batteries. When the current needed by the tramway line becomes suddenly greater, the increased armature reaction of the converter will cause a certain diminution of the pressure at the direct-current terminals. Consequently, during the time of this fluctuation the accumulators will furnish one part of the current for the tramway

and prevent the break-down of the converter.

When loading the batteries 250 cells are in series, which number may be increased up to 304. There are two sets of storage batteries, each one corresponding to one converter plant, and two automatic switches, which put the cells in and out of circuit. A remarkable constancy of pressure is obtained by the apparatus, notwithstanding the frequent and considerable current fluctuations already mentioned. One of the switches is well shown in Fig. 25; the second, larger automatic switch for 1200 ampères is used for the later converter plant. It was invented and constructed by Mr. G. Enrico, engineer of the Anglo-Roman Gas Company.

At evening time, when the lighting load is at its maximum, the storage battery alone supplies the tramway circuit.

The battery plant first put in consists of 304 cells. Its total weight of lead is about 100 tons, and the several plates of the cells can be exchanged while the plant is working. One hundred and eight of the accumulator cells are connected in groups of three cells to the above-mentioned automatic switch. The total capacity of this one battery is about 1200 ampère-hours, the normal current intensity of change being 260 ampères. The newer battery has about the double capacity, namely, 2300 ampère-hours, and its maximum charging current is about 650 ampères.

Both converter plants and storage batteries are able to supply all the current needed for the whole tramway system of Rome. All the lines have considerable grades, with a maximum of 10 per cent., and there are many sharp curves. The span wires are suspended from rosettes fixed to the sides of the houses, thus avoiding the use of poles.

One of the features of interest about the Tivoli-Rome installation, of which, within the necessarily restricted limits of a magazine article only some of the leading points could be considered, is that it is one of the pioneer works in its field. To-day a number of plants are in operation, which are, in many respects, more pretentious and more impressive in point of magnitude. When the plans for the works were made in 1888 nobody had an idea of the remarkable achievements which were so soon to be recorded in things electrical. At that time the project was considered a brilliant one, and it certainly gave to Rome the distinction of having the first electric central station from which a large amount of power was distributed over a relatively large area and to a considerable distance.

Both the Anglo-Roman Gas Company and Messrs. Ganz & Co. can, indeed, point with pride to this plant, which has not been eclipsed, despite the remarkable progress which has been made in electrical engineering since it was first started. Much of the credit for this is due to the painstaking care and ingenuity exercised by the engineers, M. Bláthy and Professor Mengarini.

The whole installation comprises a mass of detail apparatus of great variety and necessary complication, all working together in splendid harmony.

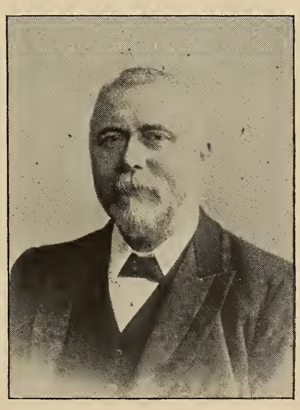
THE PROBLEM OF BATTLE-SHIP DESIGN

By E. H. Mullin

BATTLE-SHIP design has never been attended by more perplexities than just now, and Sir William H. White, Director of Naval Construction of Her Majesty's Navy, must have a hard task in bearing in absolute silence the strictures of his numerous critics. One of these says he should put comparatively heavy armour from bow to stern on his battle-ships, instead of confining it to a belt over the vitals amidships. Another wants him to construct armour belts thick enough at point-blank range to resist the projectile of any gun afloat. A third thinks he should be able to accomplish his aims on a smaller displacement than 14,900 tons for the *Majestic* class, and points triumphantly to the United States battle-ship *Oregon* and the French *Charles Martel* as the equals or superiors of the *Majestic* in armament and armour.

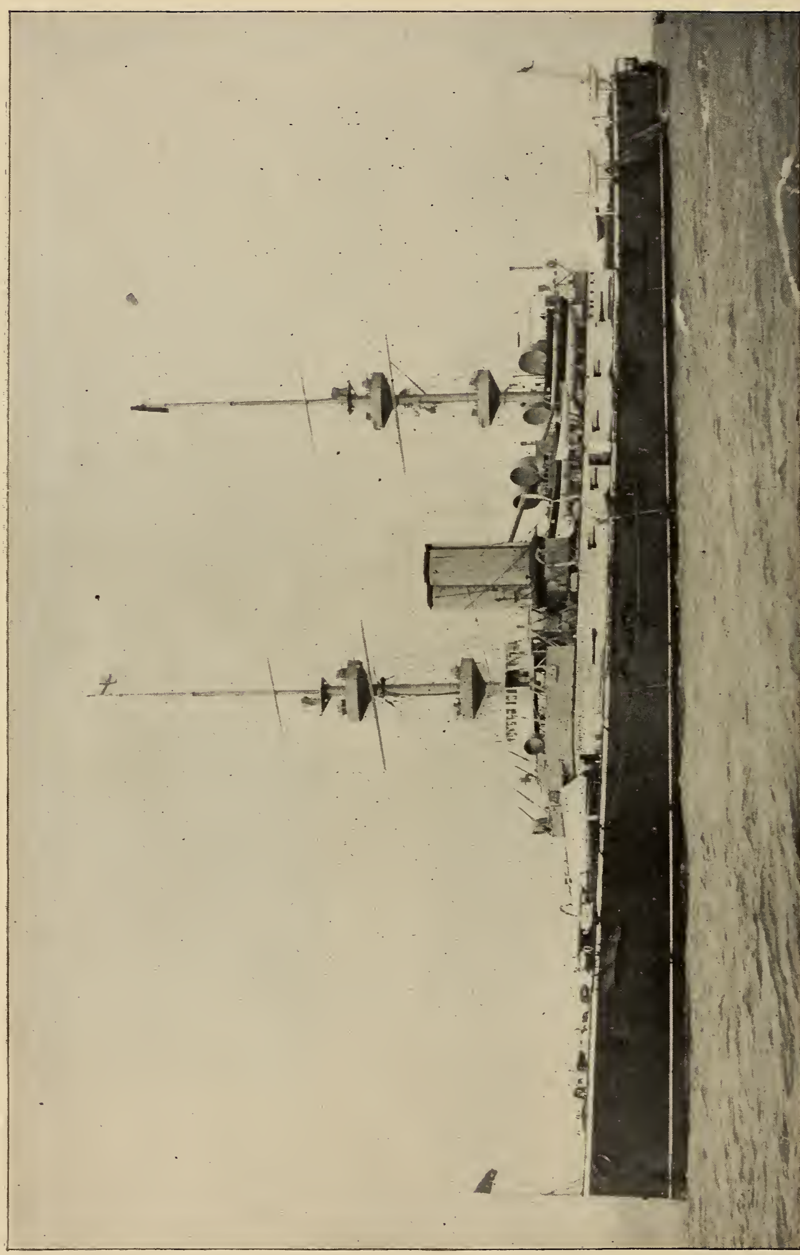
A fourth critic wants a lower free-board, in order that the warship may present a smaller target, while a fifth thinks that the freeboard of many of the British cruisers is already too low to give the guns a chance in a rough sea. A sixth thinks that too much ammunition for the quick-fire guns can hardly be carried, while a seventh is all for big coal bunkers to give the widest possible radius of action. An eighth asks indignantly what use the numerous coaling stations are to Great Britain if her warships have to carry more coal than those of any other nation; while a ninth pessimistically warns the British government that foreign fleets will reduce and occupy many of their coaling stations as soon as war breaks out.

Finally, France, as the likeliest of Great Britain's adversaries in the next naval war, has openly resolved on a plan of campaign, of which the main features are numerous coast-defence battle-ships with a swarm of torpedo-boats, and numerous fast cruisers to prey on her enemy's commerce; and this, in turn, brings out a fresh crop of critics, who affirm that Sir William White has not designed war vessels adequate for frustrating such a mode of warfare. The rules and traditions of the British naval service debar Sir William White from making direct replies to these criticisms. To do so would be to give a distinct advantage to possible opponents of British naval supremacy, who would then be able to test the theories upon which the present different types of vessels in the British fleet have been constructed.



SIR WILLIAM H. WHITE, K. C. B.
Assistant Controller and Director of Naval Construction of Her Majesty's Navy

Sir William, in one pregnant statement which he made in his article in CASSIER'S MAGAZINE, for August,



THE BRITISH TWIN-SCREW BATTLESHIP "MAJESTIC." DISPLACEMENT, 14,900 TONS. I. H. P., 10,000. SPEED, 17½ KNOTS.

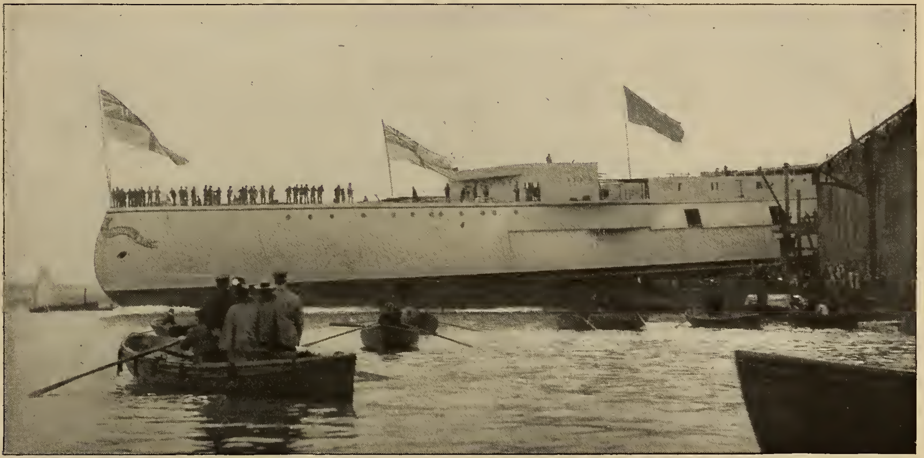
1897, answered all his past, present, and future critics when he affirmed his belief that, given certain conditions of armament, armour, supplies and speed to fulfil, the ships built by any of the great designers of the world's navies would not differ materially in tonnage.

It is thus evident that Sir William White considers himself the agent and skilled adviser of the British Admiralty in embodying in the forms of warships its plans for the defence of the Empire. The British Cabinet decides how much money is to be spent in new construction; the great fighting chiefs of the Admiralty agree at the moment as to whether battle-ships, cruisers or torpedo-boat destroyers are most wanted, and of what general type they should be; and Sir William's work then comes in through giving the greatest efficiency, at the smallest cost, in the direction indicated to him.

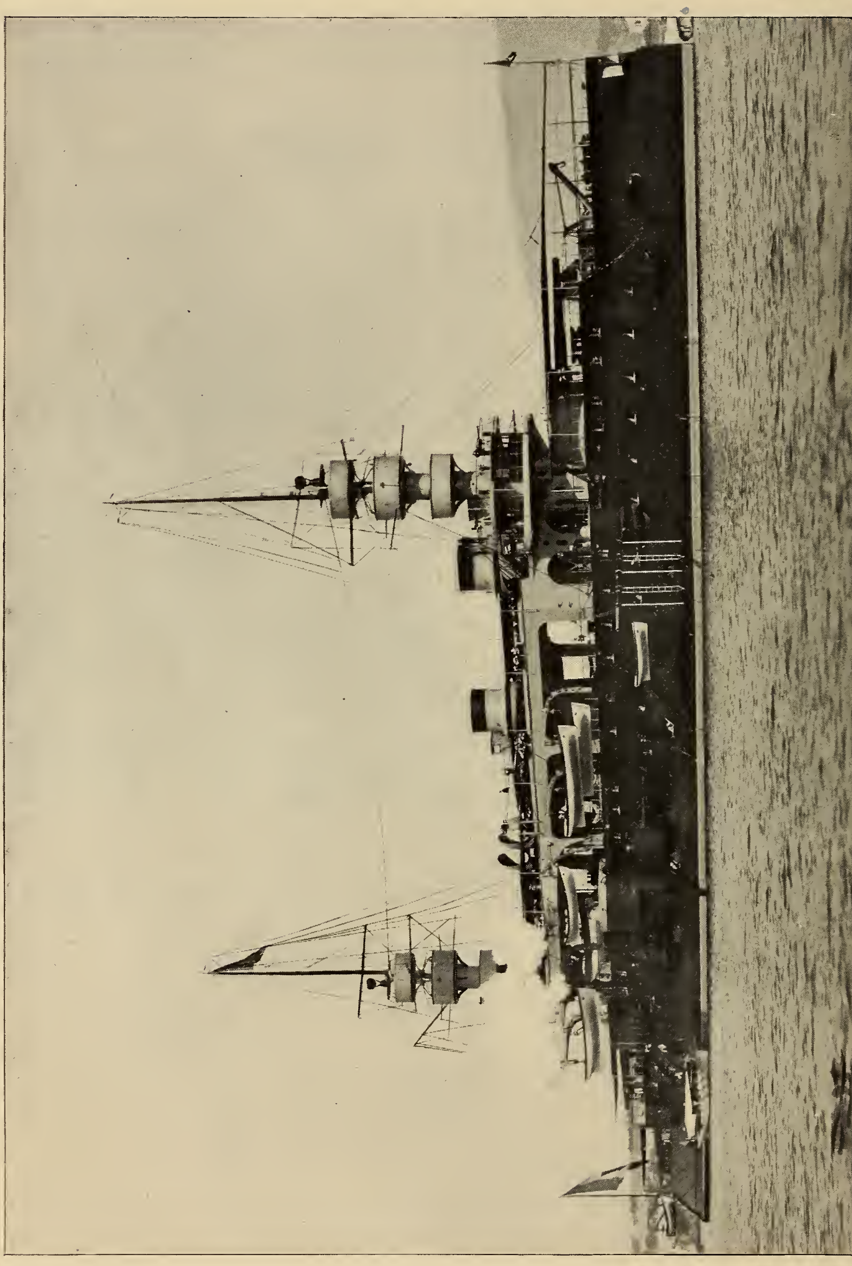
But here the difficulties which stare him in the face are far greater than those which rise up before any other chief naval constructor in the world. Other nations may contemplate, without shrinking, the possible effect of the destruction of their main fleet of battle-ships. Such a catastrophe might mean to any one of these nations, the temporary loss of outlying colonies, the shelling of its naval arsenals, or even the landing of an invading force. There would still be the country itself with its swarms of trained soldiers to be conquered, and its securely-placed capital to be captured. The whole United Kingdom, however, with its 40,000,000 of inhabitants is only one vast capital, directly dependent on distant farms for one-half its food supplies, and incapable, by reason of its extent, of being protected by military forces, like other countries' capitals which are each only a few miles square.

The British Navy is, therefore, primarily, a series of movable forts which can be placed in front of any part of the United Kingdom threatened by a foreign invader; secondly, a mobile offensive force which may change an enemy's plan of campaign by imperilling or cutting his communications with his base of operations; thirdly, a number of outpost forces to guard distant farms (colonies) and supply depots (coaling stations) against surprise; fourthly, strong escort forces to act as convoys to provision trains.

Imagine the oceans of the world turned into vast uninhabited desert plains, and think of how many millions of soldiers Great Britain would need to perform all these duties! Simply to guard her home shores Great Britain



LAUNCHING H. M. S. "CANOPUS"



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THE FRENCH BATTLESHIP "CHARLES MARTEL." LENGTH, 392 FEET 6 INCHES. BREADTH, 71 FEET. DISPLACEMENT, 11,882 TONS. I. H. P. 13,500

needs coast-defence battle-ships of moderate speed and capacity; to cut an enemy's communications, she needs homogeneous fleets of fast sea-going battle-ships with plenty of coal and ammunition capacity, covered by numerous very fast scouting cruisers; to guard outlying colonies and convoy provision fleets, she needs armoured and protected cruisers. Unlike other countries, Great Britain builds no coast-defence battle-ships, as she relegates to this duty first-class battle-ships which have partially gone out of date.

Sir William White's first and greatest problem is, therefore, to build first-class battle-ships which will be equal or superior to anything afloat. Were it not for the continual improvement going on in guns and in armour, as well as the changes rendered necessary by the results of exhaustive experimental tests or the lessons learned from the naval battles of other countries, Sir William's task would be a comparatively easy one. Like the building of the old three-deckers, it would be simply a matter of time, expense and material. But the modern sea-going battle-ship is the result of so many compromises that the relative advantages and disadvantages must be weighed in the nicest balance.

If the United Kingdom is to be protected, its fleets must be able, first, to overtake and find the enemy's fleets; second, to sink or capture their battle-ships; third, to stay above water long enough to do it. Therefore, Great Britain must, first, give its battle-ships speed and coal endurance. Other nations can afford to let their fleets jog along until they meet the enemy's, also jogging along; or, again, their fleets may lie in protected harbours until a favourable chance presents itself for some great stroke. But for Great Britain there is no safety until the enemy's fleets are destroyed. Sooner or later, the British fleets must defeat the enemy's in fair and open combat, and far better sooner than later.

Every day the war lasts adds to the risk of a successful *coup* by an active and enterprising antagonist, *e. g.*, a strong British fleet decoyed by false information to a place where it would be harmless; or "the dash on London," for which all Continental strategists are said to have plans prepared; or the capture, by surprise, of some important coaling station. Lord St. Vincent's rule, "the enemy's fleet is the English objective," is as true now as it was a hundred years ago. Only, to-day steam and calculation have replaced wind and uncertainty. The strength of a chain is its weakest link; the speed of a fleet is that of its slowest ship. Independent of other considerations, therefore, a British fleet which may have to run down an enemy's fleet on the high seas must have a minimum of speed greater than that of an equal number of the adversary's battle-ships. Sir William White has certainly stood this test, as may be seen by comparing the eight ships of the *Majestic* class, which now form the offensive power of the Channel Fleet, with eight first-class battle-ships belonging to any other nation, since the slowest of them is able to make 17.6 knots an hour under forced draught.

The *Canopus* class, four out of six of which have already been launched, will be able to make 18.75 knots an hour under forced draught, thus beating the French battle-ships *Charlemagne*, *St. Louis* and *Gaulois*, which are designed to make 18 knots.

Next to speed comes coal endurance, and here Sir William White has had to provide room in the *Majestic* for 2400 tons, or enough to take one of these battle-ships across the Atlantic under forced draught, besides making reasonable provision for auxiliary engines. What this means may be seen by contrasting the British *Majestic*, with 2400 tons of coal, with the United States battle-ship *Illinois*, which carries only half that quantity. Other things equal, the *Majestic* class would overtake an enemy's fleet, while the *Illinois* class would be delayed a day or more in the middle of the chase by having to stop to coal. This does not mean that there may not be perfectly valid reasons why the *Illinois* class should not carry more coal, but it brings into bold relief again the fundamental necessity of a British

THE "ILLINOIS," ONE OF THE LATEST UNITED STATES BATTLE-SHIPS. BUILT BY THE NEWPORT NEWS SHIPBUILDING & DRY DOCK CO., NEWPORT NEWS, VA.

fleet to find and destroy that of the enemy at all hazards.

Coming now to the second object of a British fleet, namely, "to sink or capture the enemy's fleet," it may be seen at once that this covers the efficient use of all its offensive powers. And here it is that Sir William White's opponents, led by no less a person than Rear-Admiral Lord Charles Beresford, have apparently the strongest case against him.

"What is the use," these critics say, "of building *Majestics* with 14,900 tons displacement, and then giving them a main armament of only four 12-inch and twelve 6 inch Q. F. guns, while the United States battle-ship *Kearsarge*, with 3375 tons less displacement, has a main armament of four 13-inch, four 8-inch and fourteen 5-inch Q. F. guns?"

Then the critics add up relative weights of fire in a given time, and certainly show that in many cases the British weights of fire are inferior to those of other countries. What makes the matter more curious is that Sir William White was chief constructor in the Elswick Works when the first *Esmeralda*,—the first model of the heavily-armed swift modern cruiser,—was built there for Chile in 1884. In fact, Lord Armstrong's yard on the Tyne, where the building of warships was begun under Sir William White's superintendence in 1883, has always been famous for the proportionately heavy armament of all its ships.

Lord Armstrong's patriotism is above suspicion, because it successfully stood the severe test of his being worried half to death by a lot of government numskulls when he undertook the thankless task of superintending the Royal Ordnance Factory at Woolwich between 1859 and 1863. If, therefore, Lord Salisbury and Mr. Goschen, or Mr. Gladstone and Lord Spencer, have ever felt any anxiety about the apparent under-armament of British warships, we may be sure that they have consulted Lord Armstrong and have been put in possession of his personal view of the matter as a British subject, and not as a mere builder of warships for any one who has the money to pay for them Moreover, from all that is known of Sir William White, he would much sooner resign his present office than continue to build ships which he thought were under-armed.

We are thus driven back to the theory that either Lord Armstrong approves of the present armament of British warships, or that, if he disapproves of it, his arguments have not convinced Mr. Goschen, one of the clearest-headed men living; that Sir William White is quite content with the present armament; and that Lord Charles Beresford either does not know, or undervalues, the reason for apparent under-armament. It may appear strange, perhaps, that a rear-admiral who has been a Junior Lord of the Admiralty should not know everything about the navy that there is to be known; but British official secrets are among the best-kept in the world, and are not usually intrusted to young men of 45,—Lord Charles Beresford's present age is 52,—unless it becomes necessary in the direct line of duty.

While all the reasons are not, therefore, known which make the main armament of a *Majestic* apparently inferior to that of a *Kearsarge*, some of them can be pointed out from the historical continuity of British naval policy and others from the evident purpose of British warship designs. During the long wars which followed the French Revolution, the British three-deckers were kept continually on blockade duty, except during the roughest winter weather. Both Admiral Colomb and Captain A. T. Mahan ascribe most of the superior skill then shown by British seamen to their comparative indifference to bad weather. Captain Mahan even goes so far as to trace the long succession of British naval victories over the French between 1660 and 1815 to the fact that the British were nearly always at sea with short intermissions in port, while the French were nearly always in port with short intermissions at sea. This rule still holds good to-day.

If experience at sea under all kinds of weather is to prove a valuable factor in

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THE GERMAN BATTLESHIP "KURFUERST FRIEDRICH WILHELM"

the next great naval war, then the British Navy has the advantage of every other navy in the world. The mere ordinary reliefs of 200 war vessels of all kinds at present in commission, and spread over every quarter of the globe, means in the aggregate an enormous amount of cruising through calms and storms, of steaming from cold climates to hot and *vice versa.* Out of this experience has come the prevalent British practice of having all warships good sea boats; and from this there has followed, at first perhaps unconsciously, but now as a carefully studied art, the designing of war vessels to be good gun platforms in fair weather or foul.

An observer who saw the British and French fleets meet in mid-Channel in 1895, as escorts to the Czar of Russia, who was then visiting the principal countries in Europe, says that the British ships were as steady in the choppy sea as if they had been riding in a land-locked harbour, while the French ships danced about so much that many of the officers and men were palpably seasick. Now men who are seasick are almost as much *hors-de-combat* as if they were severely wounded.

On the other hand, a warship may be a good sea vessel, and yet, owing to the low elevation of her guns, may not be able to use them in a storm. Lieutenant E. W. Eberle, U. S. N., said, in the June number of CASSIER'S MAGAZINE, last year that the United States battle-ship *Oregon*, which proved herself to be an excellent sea boat, could not have fought any of her 13-inch guns during a gale, or for hours afterward, and could have fought her 8-inch guns only at intervals in rough seas. This argument in favour of Sir William White's high freeboard in the *Majestic* and *Canopus* classes is apparently irresistible.

Next in importance in an offensive sense to a good gun platform, available in all weathers, comes sufficient protection to the men at the guns to enable them to aim steadily and shoot straight. The net result of experience with modern warships in action, from Lissa, in 1868, to Santiago, in 1898, is to show that armour-piercing projectiles are much less destructive of a crew's *morale* than shell fire. After the capture of Admiral Cervera's four armoured cruisers at Santiago, the prisoners said that they were utterly demoralised by the shells from the quick-fire guns of the American fleet. A single 8-inch shell from the *Olympia* at Manila was responsible for 29 per cent. of the casualties on the *Reina Cristina*, though the *Olympia* fired 321 shots from her 8-inch and 5-inch guns

In practice shooting, made to resemble service conditions as nearly as possible, the British Navy attains an average of 30 per cent. of effective hits, but no one expects this average to be maintained during the excitement of an action. If the *Olympia* had maintained this average at Manila she would have made ninety-six effective hits, or enough to have destroyed the whole Spanish fleet single-handed. It is, therefore, in the opinion of Sir William White and his fighting chiefs at the Admiralty, not so much a matter of the number of guns as the excellence of the shooting with those that are provided. Moreover, with 6-inch Q. F. guns, using 750 pounds of shot and cordite every minute, it becomes a matter of practical difficulty to keep more than a certain number of guns supplied.

With these data, and remembering that every pound of unnecessary material above the water-line adds to the instability of the gun platform, it can be seen how the problem has been worked out in British battle-ships. The *Majestic*, for example, has ample protection for the gunners in her heavy barbettes for her 12-inch guns. For her twelve 6-inch Q. F. guns, she has casemates with six inches of Harveyised steel armour and inwardly-projecting strong steel splinter screens. The men have ample room to work the guns, the ammunition supply through the hoists is as nearly adequate as practicable, and there is no crowded open deck to be swept by a chance shell, so that if ever men have had a chance to do good shooting in action it is on a ship of the *Majestic* class.

The weakest point in this policy ought to be its strongest one. Unless British gunners are much better shots than those of other navies, they will have fewer chances of hitting than the gunners on hostile ships with more guns of equal or superior power. The British public, therefore, ought to hold the Admiralty Board strictly accountable for the good shooting of British gunners, because, by adopting comparatively small main armaments, it has assumed that this will be the case. But good gunnery, like perfection in any other art, comes from long and continued practice, and big gun practice is a very expensive luxury. It devolves, then, upon Mr. Goschen, the First Lord of the British Admiralty, to get plenty of money for gun practice, and on the naval chiefs of the Admiralty to see that this money is spent to some purpose.

As to this point, "that the British fleet should be able to remain above water until the enemy is sunk or destroyed," this involves good armour over a warship's vitals, and numerous watertight compartments kept in good working order in time of peace. Sir William White has been blamed for not continuing the armour belt on the *Majestic* to the stem and stern, instead of allowing these portions of the vessel to remain unprotected, except for the steel deck. In order to do this he would either have to make his midships armour lighter, throw out some of his coal or ammunition, or increase the displacement. This is a matter of chances, and between a warship which has her whole length protected by medium armour and one which has thicker armour amidships with none on the bow or stern, the real question is, which would be likely to remain longest above water?

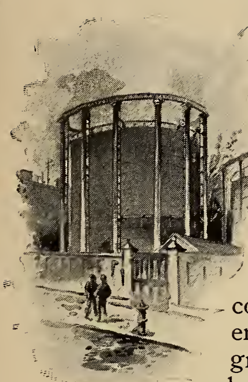
The odds are decidedly greater that the ship will be hit oftener near the middle than at the ends. An armour-piercing projectile would pass through the ends probably without killing men or disabling the ship, while if the same shot penetrated amidships, it might blow up a magazine or dismount a gun. The wise warrior, either on land or sea, takes precautions against attacks which might vitally injure his force, leaving the rest to chance and the counter-effect of his own skill. In the last resort, the leader who can kill or disable more of his opponent's men in a given time than his opponent can of his, will win the victory, whether the battle is fought between savages with simple clubs, or between trained sailors in opposing armour-clad fleets.

It is to Sir William White's credit that amidst all the mechanical complexities of the modern warship, he never lost sight of the fact that without men a warship was merely a costly lump of steel. Quick-fire guns, light and heavy, well dispersed and each with a wide angle of fire; ample protection for gunners and stokers alike; plenty of ammunition, coal and supplies; a good gun platform in rough as well as fine weather,—these were the qualities realised by him in the *Majestic*, and these have made her a favourite type for imitation by naval architects of other nations.

Most of these imitations are apparently great improvements on the original, their only drawback seeming to be their theoretically complete success in getting the traditional quart of liquid out of a pint measure. That power has never been claimed for any British warship since Sir William White became Chief Constructor of Her Majesty's Navy, now about thirteen years ago. During the first ten of those years he designed warships with 500,000 tons aggregate displacement, with 900,000 aggregate horse-power, and at a cost of £27,000,000. Even a man of ordinary calibre ought to be able to build presentable ships after such an experience, but Sir William's critics think otherwise.

THE GENERATION OF ACETYLENE

By C. A. S. Howlett



FEW chemical discoveries have attracted more scientific interest than the simple method of manufacturing acetylene gas from calcium carbide by the addition of water; yet while the principle is so very simple, the successful design of a commercial automatic generator has been food for a great deal of thought for a large army of inventors and experimenters. A very large number of patents have been issued, covering different methods of generating and storing the gas, and also special burners required to consume the gas successfully.

Possibly the crudest method of generation is to allow a stream of water to fall upon a small piece of carbide. Acetylene will be generated at once, and if a lighted match be applied, the gas will burn with a sooty flame until all the carbide is thoroughly slacked.

Another striking experiment, showing the rapid generation of the gas, is to drop a small piece of carbide, of the size of a walnut, into a tumbler full of water, and apply a lighted match to the surface. The gas will be evolved very violently, and, bubbling up through the water, will ignite and burn for some length of time, dependent upon the size of the piece of carbide. The heat of generation and the heat of the flame will warm the tumbler appreciably, but, if it be of thin glass, it will stand the heat without breaking.

Of the many methods and schemes proposed by different inventors for the automatic generation of acetylene, possibly the simplest is that adopted by some of the manufacturers of bicycle lamps and portable house lamps, in the operation of which the demand for gas, once existing, does not vary. The gas is generated by feeding the water into the carbide chamber drop by drop, continuously, while the light is wanted, safety appliances in the form of a valve or water seal being provided to allow the gas to escape if generated too rapidly. In connection with this type of apparatus, a description of the physical changes that take place may be of interest.

When a small quantity of water is brought in contact with a large amount of carbide, powdered calcic hydrate is formed which adheres to the remaining unslacked carbide and acts more or less as a shield, protecting it, in a degree, from any further intimate contact with the water, unless some mechanical, chemical or other equally efficient means are provided for removing this substance as soon as it forms. This white, powdered coating, if not removed, will bring the element of time into the manufacture of the gas, preventing instantaneous generation by absorbing a considerable quantity of water before it can reach the fresh carbide. When the water supply is shut off, the moisture contained in the refuse will gradually combine with the unslacked carbide and continue to generate gas for an appreciable time, the amount being dependent upon the quantity of refuse, the amount of carbide present, and the quantity of water absorbed in the refuse.

In many of the generators of this type no provision is made for the separation of the slacked from the unslacked carbide, or for the storage of the gas generated after the demand has ceased, and consequently, when so constructed, they cannot be considered a practical commercial commodity. This over-

production of gas after the demand has ceased is the greatest bugbear that the designer of a practical automatic acetylene gas generator for general illuminating purposes has to contend with, and unless precautionary measures are adopted to guard against it, is liable to be accompanied with more or less serious consequences.

The form in which the carbide is introduced into the generators of this type has demanded much attention. Some designers use the carbide in a semi-powdered condition, made into cartridges, presumably under pressure, incased in an absorbent paper covering. Other designers in this class use the carbide in a granulated state, incased in a tin cylinder provided with a central perforated tube into which the water is allowed to drop. Others use absorbent paper partitions to subdivide the mass of carbide, while some use glass disks. The carbide is used by others in its normal state, contained in a number of shallow iron pans having solid bottoms and perforated sides, the water being fed into the calcic carbide chamber from below.

Another successfully practised scheme of automatic generation is an adaptation of the well-known principle of the hydrogen gas generator. In this the supply of carbide is brought in contact automatically with a comparatively large body of water. The carbide receptacle is attached to the top of a gasometer. As the gasometer falls, the carbide comes in contact with the water, and the gas which is generated forces the gasometer up, thereby removing the carbide from intimate contact with the water. The gas generated from the moisture absorbed by the refuse, and also that generated by the vapours arising from the surface of the water, is taken care of by gasometers of ample capacity. As the gasometers fill, they automatically shut off any further supply, and if the generator should be filled, a safety appliance is provided which allows the gas to escape out of doors.

If the demand be intermittent, as is the case when the gas is used for general illuminating purposes, this type of generator should never be employed unless provided with a sufficiently large reservoir to hold all the gas that the amount of carbide used is capable of generating, or by making the containing vessel sufficiently strong to withstand the consequent increase in pressure. When an increase in pressure is employed, automatic reducing valves or governors should be used to reduce the pressure from whatever it may be in the generator to one equivalent to a column of water between two and three inches in height, at which pressure the acetylene burners give the best results.

An obsolete form of generating apparatus which gave much promise and was used by one of the owners of the largest carbide factory, and which met with some success, consisted of a cylindrical steel tank, capable of withstanding an appreciable pressure, which acted as a gas generator, a gasometer, and dryer combined. The carbide, 250 pounds of which was used in one of the smaller sizes, was placed inside, in a cylindrical wire cage mounted on a shaft which passed through a stuffing box and was provided with a crank, the outfit resembling an ordinary peanut roaster or squirrel cage. A pipe for the admission of waterwas suspended above the carbide cage.

The generation of gas was wholly dependent upon the pressure or amount of gas in the tank. As the gas was used, the pressure fell, opening an automatic water valve. The increased pressure closed the water valve, and any gas generated after the water supply was shut off, due to the moisture in the refuse, was confined in the tank until used. A reducing valve or gas governor, connected to the service pipe, reduced the pressure from between one-quarter of a pound to five pounds per square inch down to a constant working pressure of between two and three inches of water. A gauge was provided which showed the pressure at any time, and also a safety valve which allowed the gas to escape if the pressure exceeded a reasonable amount.

A later machine, quite novel and

simple, consists of a series of isolated receptacles, arranged in steps, each holding a comparatively small quantity of carbide and all connected by means of pipes to a common gasometer and automatic water feed. There are a number of types, styles and designs of automatic water feed, all accomplishing the same result, namely, introducing water into the carbide receptacle automatically as the gas is consumed. The gasometer is of such a size that it will hold all the gas generated after the demand ceases at any time. As the gasometer falls, it automatically turns a water cock, allowing the water to rise from below and enter the lowest receptacle. After slacking all the carbide in the first chamber, the water rises to the next, and so on through each compartment. This arrangement has given very good results.

Designs also have been suggested where the water is fed into the carbide chamber by a system of one or more wicks, one end of which may be moved, permitting it to be raised or lowered as more or less water is required.

An entirely different class of designers propose to prepare the carbide in small parcels, using automatic mechanism to feed them into the water chamber as required. This special preparation of the carbide necessarily adds to the cost of maintenance per burner-hour.

Others intend to have the carbide cast into cylindrical cartridges, coated with a slowly soluble glaze, and to generate the gas by inserting one of these cartridges, weighing a pound, into the water chamber. The generation goes on regardless of the demand, and the receptacle is made strong enough to withstand the increase of pressure due to continued generation. A gas governor is used to reduce the pressure and keep it constant in the service pipes.

Designers should keep in mind the fact that the refuse occupies a much larger space than the carbide from which it is made, and that when the gas is generated from a small bulk of carbide, provision should be made for the dissipation of the heat of generation which is liable to become quite appreciable if the generation be continued for a long time.

Acetylene may be either consumed in its pure state, or used to enrich the ordinary illuminating gas supplied through city mains. Used in its pure state in special burners consuming one-half of a cubic foot of gas per hour, it gives a very white and beautiful light of twenty-five candle power. The brilliancy of the flame would suggest the highest possible incandescence, yet its temperature is only 900 degrees C., whereas that of the less brilliant ordinary coal gas flame is 1300 degrees. There is no tinge of colour such as is found with the electric light and incandescent gas burners. The flame is not easily extinguished by the wind, and the diffusive power of the rays is unexcelled by any illuminant. All colours seen in this light appear in their natural shades.

It has been used with marked success in photography. A spectrum analysis shows identically the same range of colours as sunlight, and a prominent photographer found that excellent negatives could be made with it with almost the same speed as in daylight. The Camera Club, of St. Catharines, Canada, placed an acetylene gas apparatus in its studio, which is one of the finest equipped galleries in Canada, and has for some time been carrying on extensive experiments. Several of the members are quite enthusiastic over the result, and claim that beautifully lighted portrait studies can be as readily made with this light as by daylight. The gas is not powerful enough to allow snap shots in the studio, but magnificent results can be obtained from a three to five-second exposure, or longer, dependent upon the number of burners and their arrangement. The writer has obtained fairly good results in photographing machines with six one-half-foot burners in a room 12 × 15 feet, with ten seconds' exposure.

Since for the same number of burners a very much smaller number of cubic feet of acetylene is required than with ordinary gas, no alterations are necessary in the piping customarily used.

The products of combustion are the same as from the complete combustion of coal gas; that is, carbonic acid gas and water vapour. Due to the extreme richness of the gas, a greater percentage of air can be mixed with it without seriously affecting its luminosity, than with ordinary gas.

Ordinary gas, burnt in an especially constructed acetylene burner, gives less than one-tenth of its true lighting power, and acetylene, burnt in a common gas burner, gives a large, intensely brilliant flame accompanied with a great deal of smoke, and when turned down to a small flame it deposits soot, clogging the burner, if the opening consists of a straight slit. Even the very fine fish-tail burners, with a straight slit, intended for rich oil gas, suffer from this defect when the acetylene flame is turned down.

The choice of a burner and the mode of using it are very important factors in determining the value of this or any new illuminant. Acetylene cannot well be burned in an argand burner as ordinarily constructed, or with the devices that succeed with petroleum lamps. It is necessary, for satisfactory results, to use special burners, constructed solely for acetylene. Those that are meeting with much success have two, and, in the larger sizes, three small circular impinging flames, which, after meeting, form a flat flame of small area, but intensely white in colour.

Like all other illuminating gases, acetylene will explode if mixed with air in the proper proportions and ignited. When one volume of air is mixed with one volume of acetylene in a tube of uniform diameter, and ignited, a dull red flame runs down the cylinder leaving behind a mass of soot and throwing out a dense mass of smoke. When acetylene is mixed with 1.25 times its own volume of air, the mixture begins to be slightly explosive, the explosive violence increasing until it reaches a maximum with about twelve times its volume of air; then it gradually decreases in violence until, with a mixture of one volume of acetylene to twenty of air, it ceases to be explosive.

A very important rule, essential for the safety of the experimenter with acetylene, is to avoid, in general, the ignition of all mixtures of air and gas, as any illuminating gas mixed with air and ignited is liable to explode with more or less serious consequences. If acetylene be introduced or generated in a confined space, it will mingle with the air which originally filled the space, and form, possibly, a very explosive mixture. This mixture may or may not be dangerous to ignite, as the explosiveness is dependent upon the conditions under which the ignition takes place.

If the mixture be under a suitable pressure, that is, one equivalent to a column of water two or three inches high, and the gas pipe provided with a special acetylene burner, it may be lighted with perfect safety, but it must never be lighted at an open pipe not provided with a proper burner, as the flame is liable to run back through the pipe to the gas holder and cause a serious explosion.

The mixture will, at first, burn with a small bluish flame, due to the air present, and grow gradually whiter as the percentage of air decreases, the pure acetylene burning with a steady, very white, and practically wholly luminous flame of very high candle-power.

While the quality and quantity of the light is all that can be desired, its limited adoption is incompatible with the universal interest shown when it was first offered to the public.

THE UNITED STATES REVENUE CUTTER SERVICE

By Captain John W. Collins, Engineer-in-Chief of the Service

IN the early days of the American Republic, Alexander Hamilton, the first Secretary of the United States Treasury, appreciating the value of sea-fighting power, organised, in the year 1790, a revenue marine corps which is now known as the Revenue Cutter Service. Antedating, as it does, by about eight years the formation of the regular United States Navy, it was, as a matter of convenience, placed under the direction of the Treasury Department, of which its founder was the illustrious head. By act of Congress, approved July 1, 1799, the President of the United States was authorised to "cause the revenue cutters to be employed to defend the sea coast, and to repel hostility to vessels and commerce within their jurisdiction."

The first defensive attitude of the newly created marine in obedience to this legislation was in suppressing piracy along the Southern coast, which was becoming insupportable. Notwithstanding their inferiority in size and armament, the cutters did not scruple to attack, with an obstinate determination to conquer, the ships of these desperadoes, and by the exercise of constant vigilance discovered their bayous of resort and completely broke up their harbouring therein. An efficient patrol of the Atlantic coast was also maintained by cutters for the enforcement of the law of 1794, inhibiting the slave trade.

The power vested in the President of the United States to order vessels of the revenue cutter service to co-operate with the navy in time of war, in defensive or offensive operations on the coast or on the high seas, is an authority which he can exercise over no other branch of a civil establishment, and conclusively proves that the revenue cutter service is essentially a part of the armed force of the nation, identical in character with the naval service, since it is both nautical and military, and always ready for action.

In every naval warfare conducted by the United States it has taken a prominent part. During the difficulties with France at the close of the last century, the little fleet of cutters, then numbering twenty, was employed constantly, and, by its unaided efforts, captured sixteen of the prizes taken from the French. The names of the historic *Constellation* and *Constitution* were enrolled at that time upon the list of revenue cutters, as well as that of the *Pickering*, which made an exceptionally fine record during her two cruises to the West Indies by capturing ten prizes.

In the War of 1812 the revenue cutters were again called upon to co-operate with the navy in inforcing the embargo laws. Fourteen of the British vessels taken at this time were secured by them, the first prize of the war having been taken by the cutter *Jefferson* only a week after the declaration of hostilities. Among the valorous deeds performed by their officers and men was the engagement of the small cutter *Surveyor* with the British frigate *Narcissus*. Although defeated by overwhelming

THE UNITED STATES REVENUE CUTTER "BEAR," NIPPED IN THE ICE NEAR POINT BARROW.

numbers, the bravery displayed caused the British commander to return to Captain Travis, of the *Surveyor*, his sword, accompanied by a letter extolling his gallant conduct.

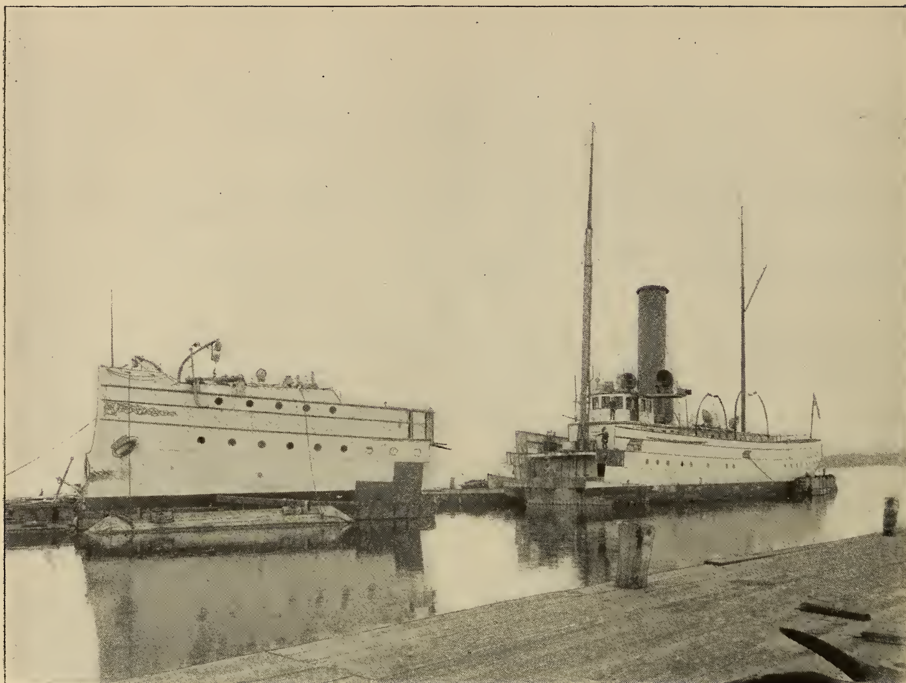
In 1836, when the Seminole Indians assumed an inimical attitude towards the United States, revenue cutters were at once ordered to the scene of disturbance, and until the close of the war, from three to five of these vessels remained near the coast of Florida, rendering such effectual aid to both army and navy as to call forth words of strong commendation from the naval officer in command. Upon one occasion Captain Hunter, of the cutter *Jackson*, landed his guns at Saint Marks and warded off a meditated attack upon that town.

In 1815 and for a number of subsequent years some of the most intrepid officers of the Navy sought and obtained commissions in the revenue cutter service on account of the excellent scope which it afforded for seamanship and gallantry. Lieutenant Paine, in command of one of its vessels, represented the United States in the waters contiguous to the British provinces on the American northeastern frontier during the fisheries trouble which followed the treaty of 1818, and discharged this delicate and responsible trust in a most praiseworthy manner. During the Mexican war, several cutters participated in the naval operations as blockaders and dispatch boats, one of them, the *Woodbury*, acting as auxiliary to General Taylor's army of occupation during his advance upon Brazos and Corpus Christi.

Captain John Faunce, who, in command of the cutter *Harriet Lane*, accompanied the Paraguayan expedition, had the well-deserved honour of receiving a letter from the commodore of the fleet, in which he praised this vessel as the most efficient ship in the squadron. It was the *Harriet Lane* which steamed first to the relief of Fort Sumter, and, later on, during the American Civil War, shared in the attacks upon Newport News and Hatteras Inlet. The cutter *Miami* distinguished herself in the attack upon Sewell's Point and by covering the landing of troops at Lynn Haven Bay for the recapture of Norfolk.

The *Naugatuck* served with Admiral Rodger's ironclads at Fort Darling, and

THE "THOMAS CORWIN." ONE OF THE OLDER TYPE OF CUTTERS.



THE "GRESHAM" IN TWO SECTIONS FOR PASSAGE THROUGH CANAL LOCKS

also participated in the bombardment of Drury's Bluff; the *Forward* arrived promptly at Annapolis to meet and give support to General Butler's forces, and the *Nemaha* received General Sherman on board after his famous march to the sea and conveyed him to the fleet of gunboats lying below Savannah, prior to the evacuation of that city, when Sherman wrote the brief note to President Lincoln beginning, "I beg to present you, as a Christmas gift, the city of Savannah."

Several cutters aided the operations of the Potomac flotilla in Chesapeake Bay by preventing the transportation of supplies from North to South; and Captain Thomas M. Dungan, in command of the cutter *Reliance*, was killed in action near the coast of Virginia. Two survivors of the *Monitor's* memorable battle with the *Merrimac* off Hampton, Va., are now officers of the cutter service, namely, Captain L. N. Stodder, who was presented with a gold medal in ecognition of his brave conduct on that trying occasion by the citizens of his native town, Boston, and Lieutenant Samuel Howard, who, as a volunteer, acted as pilot to the vessel during her fight, a duty requiring most skilful seamanship, considering the treacherous nature of Hampton Roads. Other instances of daring and bravery in which cutters were engaged are flatteringly referred to by Admiral Porter in his "Naval History of the Rebellion."

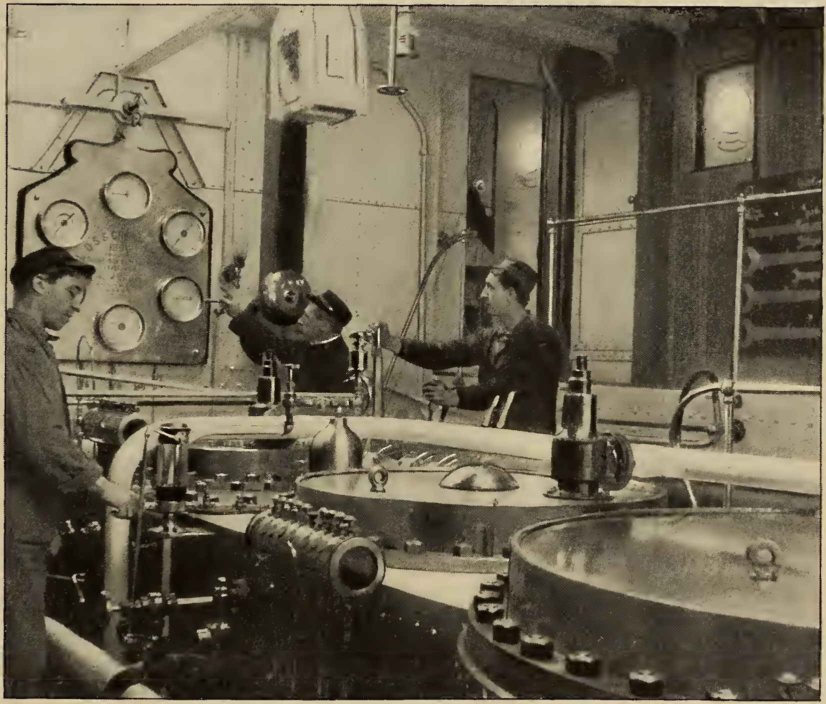
Many people associate the civil duties of the revenue cutter service merely with the apprehension of smugglers and other violators of the customs laws. As a matter of fact, this forms but a small portion of the multifarious duties assigned to this service by various acts of Congress. It can be safely said that no other single branch of the government combines, as its duties, so many and such varied operations. In addition to co-operating with the navy in time of war, and in special missions in peace times, the cutter service is required to strictly enforce all statutes relating to

the maritime interests of the country. These include the customs, navigation, steamboat inspection and quarantine laws, enforcing neutrality, and suppressing mutinies aboard merchant vessels.

Revenue cutter officers are, by law, also detailed as inspectors of life-saving stations, and are held accountable for the drilling and disciplining of the crews of surfmen. They supervise the construction of the buildings and boats belonging to the life-saving service, and much of the present high standing of this beneficent institution is due to these inspectors. In fact, the bureau of life-saving is but an offspring of the revenue cutter service, it having been founded by Hon. Sumner I. Kimball while holding the position of chief of the revenue cutter service.

In recent years, revenue cutters have been directed to enforce the rules relative to the anchorage of vessels in the ports of New York and Chicago, and to regulate the speed of vessels passing through the Sault Ste. Marie Canal. An annual proclamation is also issued by the President of the United States, directing all revenue cutters between Eastport, Me., and Cape Hatteras to constantly patrol the coast during the winter months for the purpose of rendering aid to ships in distress. Millions of dollars' worth of property and many lives have been saved by these cutters, and the reports sent in teem with thrilling tales of the rescues of shipwrecked mariners.

On January 18, 1884, for example, the steamship *City of Columbus*, of the Boston and Savannah Line, on her regular trip to the South, struck on Devil's Bridge Reef, off Gay Head, Mass., at 3.30 in the morning, and sank almost immediately. There were on board at the time eighty-two passengers besides her regular crew of forty-five men, most of whom went down with the ship. A number, however, took to the rigging, where they were discovered by the cut-



IN THE ENGINE ROOM OF THE "GRESHAM."

THE U. S. REVENUE CUTTER "MCCULLOCH." THE FIRST SHIP FIRED AT BY THE SPANISH IN THE BATTLE OF MANILA BAY, MAY 1, 1898

ter *Dexter*, which, very opportunely, was cruising in the vicinity.

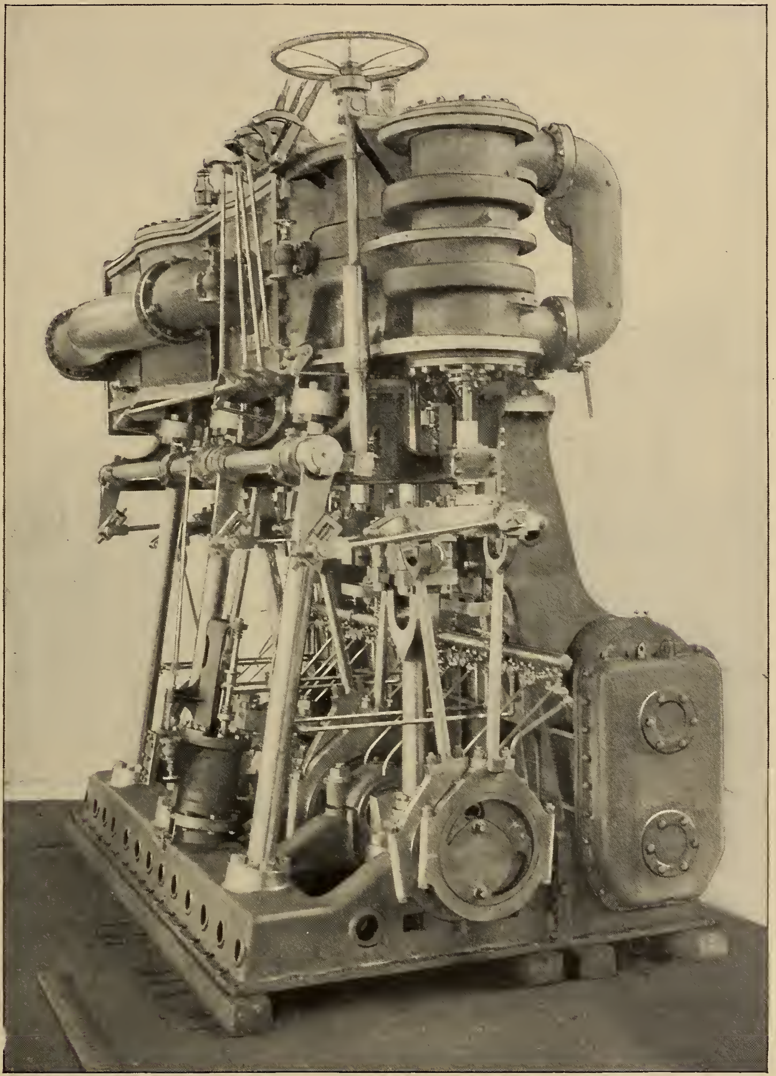
Notwithstanding the fact that a fierce gale was blowing, and the *Dexter* was rolling her bulwarks under with every move, she instantly started to the rescue. To lower a boat in such a boisterous sea in order to reach the wreck was extremely hazardous, and a feat from which the most courageous would recoil. The attempt was made, however, and nineteen survivors were taken from the frozen rigging in an almost dying condition. One of the officers, in charge of a boat's crew of four men, jumped into the icy water and swam to the wreck twice, to save two persons who could be seen lashed to a spar. Upon reaching them, he found that both had perished from exposure; but, persisting in his efforts, he succeeded in recovering the bodies.

Another instance where a number of lives were saved was that of the wreck of the passenger steamer *Metis* off Watch Hill, R. I., on August 30, 1872. The cutter *Moccasin* went to her assistance at once, despite the opposition of a high wind, and succeeded in saving the lives of forty-two passengers and in recovering seventeen dead bodies from the wreck. For this meritorious act the officers and men of the *Moccasin* received the thanks of Congress by joint resolution, approved by President Grant, January 24, 1873.

The patrolling of Bering Sea for the prevention of pelagic sealing, and the enforcement of the regulations of the protocol entered into with Great Britain, is now, and has been, for the past five years, entrusted entirely to revenue cutters. Five vessels are annually dispatched to Alaskan waters, and the vigilance of their patrol is attested by the almost complete suppression of illicit sealing within the enclosed zone. The cutter *Bear*,—which was originally a Dundee steam whaler, constructed solely with the idea of navigating amid ice fields in Arctic regions,—makes cruises each year to Point Barrow, the northernmost part of the North American continent, and to the northeast coast

of Siberia, to transport the reindeer that are purchased by the United States government to Teller Reindeer Station, at Port Clarence, Alaska.

Such an expedition had never before been undertaken at the beginning of the winter season, and it was acknowledged by the most experienced Arctic navi-



TRIPLE-EXPANSION ENGINE OF THE "MCCULLOCH

In the latter part of November, 1897, the *Bear* was sent with a relief expedition to Point Barrow, where, it had been learned, five whalers had been crushed in the ice, and their crews, consisting of 250 men, were in danger of starvation.

gators to be a perilous adventure. Volunteers were called for among the crew, and, without an exception, every officer and enlisted man was found willing to go, although they had just returned from the long annual trip so full of dis-

comforts and dangers. Many other officers volunteered their services, among them Lieutenants Jarvis and Bertholf, who were to lead the overland expedition.

Promptly on the day set, the *Bear* left Seattle for her destination, which, according to preconcerted arrangements, was the mouth of the Yukon River. In spite of the strong head winds with which her course was beset, the staunch craft arrived a few days before Christmas, 1897, only to find that the ice had already formed in the river to such an extent as to prevent a landing. As rapidly as possible the vessel proceeded down the coast, seeking a place for disembarkation, when, about 200 miles below the mouth of the river, clear water was discovered and a successful attempt was made to put the two officers on shore.

The *Bear* fought her way through the rapidly forming ice-pack until she reached Unalaska, where she spent the winter. The overland expedition reached the mouth of the Yukon in safety and left there for the reindeer station, where it was intended to secure a herd of the government's reindeer and drive them to Point Barrow as a food supply until the *Bear* should come in July or August. The *Bear* was caught in the pack-ice near Point Barrow from August 2 to August 16, 1898, but finally worked herself clear on the 17th, rescued the men and landed them safely at Seattle on the 13th of the following month.

Prior to the late war with Spain, revenue cutters on the southern United States coast were employed in intercepting filibustering expeditions leaving American ports. Although a few managed to elude their watchfulness, many were apprehended, and the vessels and

THE "MANNING," A SISTER SHIP OF THE "MCCULLOCH"

THE "HAMILTON"

cargoes confiscated. The various cutters which co-operated with the navy played conspicuous parts. In the naval attack on the Spanish fleet at Manila, the *McCulloch*, which accompanied Admiral Dewey's squadron from Hongkong to the Philippines, was the first vessel to be fired upon.

Probably the arrival of no vessel in modern times was so anxiously waited by the nations of the civilised world as was that of the *McCulloch* at Hongkong when it became known that she would bear the first authentic reports concerning the great victory at Manila Bay. No better vessel could have been selected by Admiral Dewey as a bearer of dispatches, for the *McCulloch*, with the exception ot the three largest ships, was the most speedy traveller in the fleet.

As a representative of the new type of revenue cutters, a brief description of the *McCulloch* may be of interest. She is 219 feet long, over all, 33 feet 4 inches breadth of beam moulded, and has a displacement, at 14 feet mean draught, of 1280 tons. She is of composite build;

THE U. S. REVENUE CUTTER "WOODBURY"

that is, constructed of steel, except that under water, instead of steel plating, wooden planking is secured to the frames. As this planking is sheathed with copper, the vessel has the great advantage of being able to keep at sea for long periods without requiring frequent dockings for the removal of barnacles and other marine growth, as is the case with all steel vessels.

In order to prevent galvanic action, due to the copper sheathing, the stem, stern frame, propeller and rudder are constructed of manganese bronze, which, although very much more expensive than iron or steel forgings would be, also prevents any deterioration due to corrosion, and at the same time provides practically as great structural strength as the forged steel. The wooden planking is of the best selected Oregon fir, and extends from the wooden keel to a sheer line about two feet above the normal water-line. The planks are secured to the steel frames by Tobin bronze bolts, the heads of the bolts being let into the planks on the outside, and covered with wooden plugs.

The main and berth decks are continuous fore-and-aft. The forecastle and poop decks extend about one-quarter the length of the vessel fore and aft, respectively. The vessel is provided with a collision bulkhead, and water-tight bulkheads between each main compartment. The crew's quarters are forward on the berth deck, and the accommodations are ample for sixty men. The captain's quarters are aft on the main deck, and are commodious, well-lighted and ventilated. The ward room is on the berth deck, aft, and is fitted with an athwartship mess-room in addition to eight large state-rooms for the officers. As the vessel was built with the intention of being assigned as the flagship of the Bering Sea patrol fleet, she is fitted with every convenience for the comfort and health of her officers and crew.

She is rigged as a three masted schooner, and has a bowsprit and jib-

DRILLING WITH A HOTCHKISS RAPID-FIRE GUN ON BOARD THE REVENUE CUTTER "MORRILL"

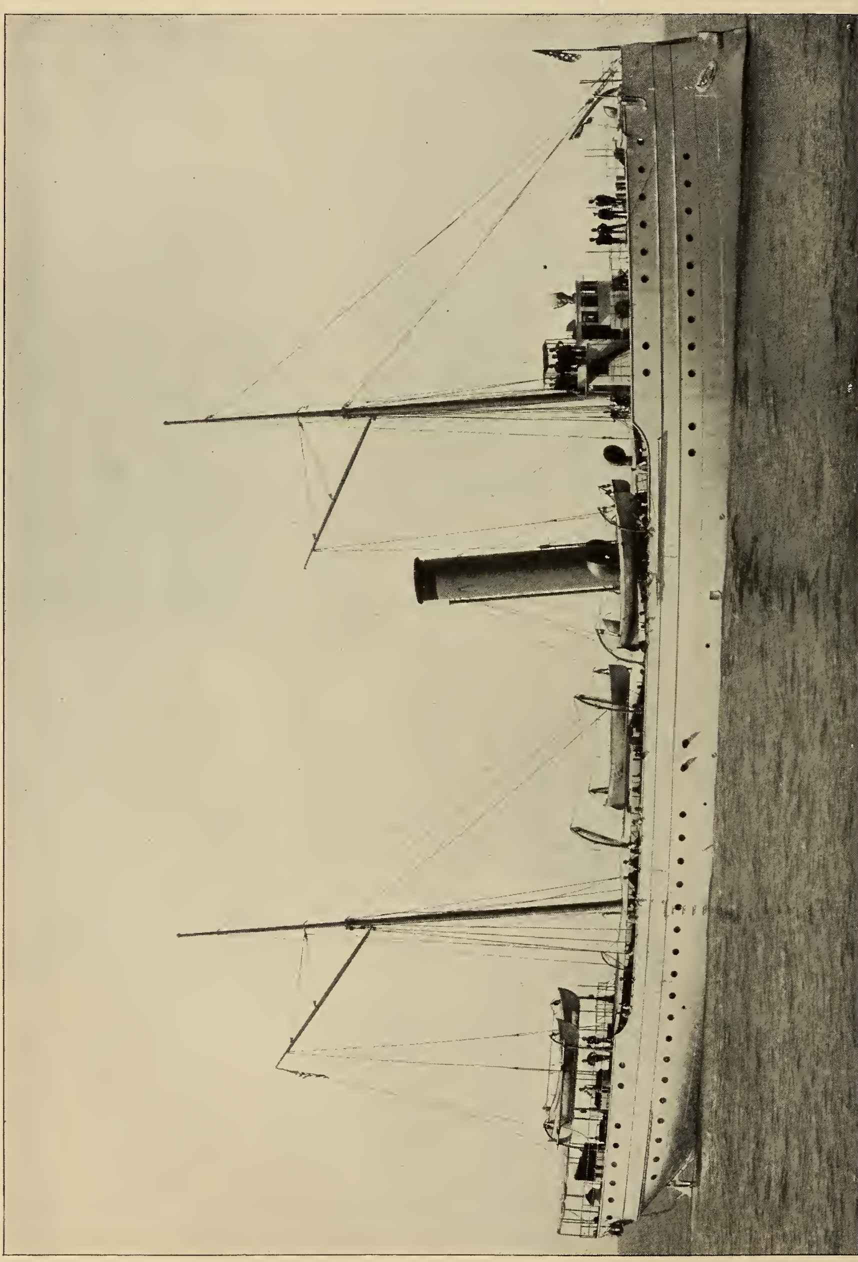
boom, thus enabling her to carry a large sail-spread as an auxiliary for slow cruising. There is a steam steering engine, steam windlass, and all other apparatus necessary in the outfit of a modern cruiser or gunboat. The sanitary and drainage systems are complete with every necessary detail that ingenuity can devise.

The propelling machinery consists of one vertical, direct-acting, triple-expansion engine, with cylinders 25 inches, 37½ inches and 56¼ inches, diameter, respectively, with a common stroke of 30 inches. The general design is a compromise between naval and mercantile types, combining, to a certain extent, the advantages of both. All materials entering into the construction of the engine are of the best quality which the most careful inspection will secure, and no sacrifice has been made to obtain reduction in weight.

All three cylinders are provided with working linings, and the high and medium-pressure cylinders are steam-jacketed. The high-pressure cylinder is fitted with a piston valve, and the other two cylinders with double-ported slide valves, all operated by the Stephenson link motion, with double-bar links. The air pump is independent, and of the double vertical type, bolted directly to the condenser which forms a part of the framing of the main engine. The circulating pump also is independent, and of the centrifugal type, driven by a vertical engine.

Four single-ended Scotch boilers furnish steam at a maximum pressure of 160 pounds. Each boiler is 11 feet 6 inches in diameter by 10 feet long. A distilling apparatus, capable of producing 3500 gallons of fresh water per day, is provided. There are also a complete electric light plant, including a search-light, a hydro-pneumatic ash ejector, steam reversing gear, a machine shop containing a lathe, shaper and drill press, and all other appliances necessary for long, continuous cruises.

Her armament in time of peace con-



THE "ONONDAGA," ONE OF THE LATEST OF THE U. S. REVENUE CUTTERS. BUILT BY THE GLOBE IRON WORKS COMPANY, CLEVELAND, OHIO

sists of two 3-inch rifles, and four 6-pdr. rapid-fire Hotchkiss rifles. Vessels of her class which co-operated with the navy during the war with Spain are armed with three 4-inch rapid-fire rifles, six six-pounder Hotchkiss rapid-fire guns, and four Colt machine guns. In addition, each vessel is provided with a fifteen-inch torpedo port, located in the stem. The *McCulloch's* coal capacity is 280 tons, which, under economic cruising, gives her a steaming radius of about 5000 miles. The speed developed on her trial trip was 17.2 knots, or about 5 knots more than vessels of her class in the regular navy. She was built by the Cramps, of Philadelphia.

The *McCulloch* has four sister vessels, the *Manning*, *Gresham*, *Algonquin* and *Onondaga*. The steam machinery of all five is identical, and their general description is practically alike with the exception of their hulls. The *Manning's* is composite, like the *McCulloch's*, the part that is under water being of wood, while the *Gresham*, *Algonquin* and *Onondaga* are entirely of steel. The three last-named vessels were built at Cleveland, O., but are now doing duty along the Atlantic coast. In bringing them through to the coast it was found that the shortest locks in the canal system between Ogdensburg, N. Y., and Montreal made it necessary to cut off a portion of the bow of each vessel, about 35 feet in length, to be subsequently fitted together again. The illustration on page 376 shows one of the cutters so divided. The *Manning* was built at Boston.

The revenue steamer *Corwin* is a fair example of the older type of cutters at present in commission. This vessel is a single-screw wooden steamer, 145 feet 6 inches long, over all, 23 feet beam, and displacing about 325 tons at a draught of 11 feet 5 inches. Her propelling machinery consists of a vertical engine with cylinders 34 inches in diameter by 34 inches stroke, capable of developing about 400 horse power. The average speed of this class of vessels is between 10 and 12 knots.

Notwithstanding the small size of the *Corwin*, no other vessel owned by the United States has performed such valuable and hazardous duties as have fallen to her lot. She has carried three Arctic relief expeditions to the far north, and nearly every year since 1876 she has made long cruises in Bering Sea and Alaskan waters. Her officers have made many explorations into the uncharted rivers and bays of the great northwestern territory and have obtained information of the greatest value respecting this almost unknown region.

One of the most daring and hazardous feats of the recent war with Spain was performed by the little revenue cutter *Hudson*, commanded by Lieutenant F. H. Newcomb, off Cardenas, Cuba, when, in the face of a heavy fire from the Spanish shore batteries, she steamed in and towed the disabled torpedo boat *Winslow* out of range of the enemy's guns. Armed with only two six-pounder rapid-fire guns, she made a valiant fight against the much superior force on shore. Although her smokestack and ventilators were riddled by shots, not a man on board received the slightest injury.

All revenue cutters co-operating with the navy are in command of cutter officers, and the crews are enlisted men belonging to the same service. In the cable-cutting expedition at Cienfuegos harbour, the cutter *Windom*, on account of her light draught, was sent in ahead of the naval ships to clear the way for the small boats containing the men who volunteered to cut the cable. One well-directed shot from her four-inch rifle demolished the lighthouse which a number of Spanish troops had utilised as a fort for the purpose of firing on the boats' crews. The cutter *Morrill*, while pursuing a Spanish schooner which attempted to run the blockade off Havana, was fired on by the Santa Clara batteries. Without hesitation she returned the fire of these forts, and it was by remarkably good fortune that she escaped demolition from a ten-inch shell which burst directly over her pilot house.

There are, in all, forty revenue cutters, the majority of which, during the Spanish war, co-operated with the navy

THE "RUSH"

in the vicinity of Cuba, or assisted army officials in laying submarine mines for the protection of harbours along the Atlantic and Gulf coasts. With but a single exception the cutters which acted as auxiliaries to the navy were in active engagements, either in attacks on shore fortifications or in covering landing expeditions of United States troops.

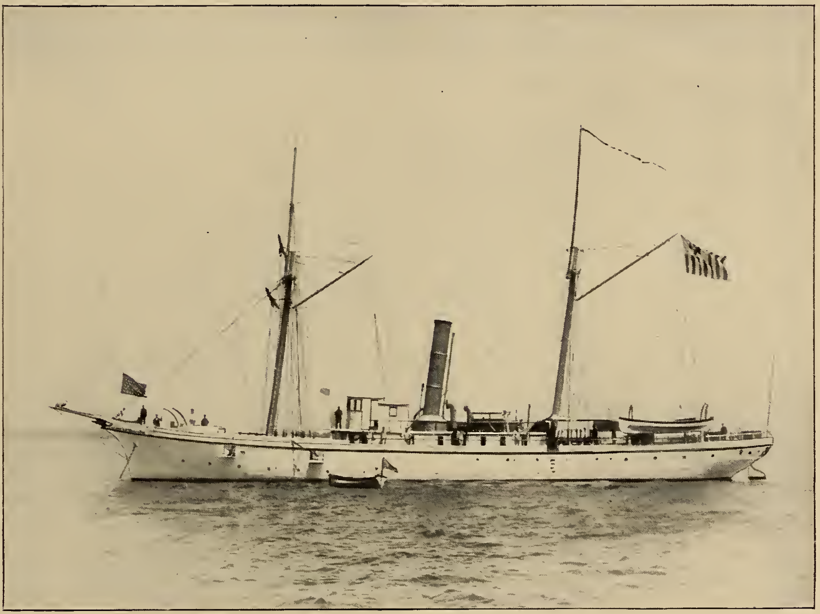
The cutter service, as stated before, is under the control of the Secretary of the United States Treasury, except when, in time of war, its vessels and crews are, by order of the President, placed under the direction of the Secretary of the Navy. Its officers are appointed and commissioned by the President in the same manner as officers of the navy. Its crews are enlisted for periods of three years. Naval discipline prevails on board all of its vessels, and the men are drilled in the handling of guns and small arms. At the close of the Civil War, a large number of the volunteer officers of the navy were given commissions in the revenue cutter service; but as these could not supply all the existing vacancies, Congress, in 1876, passed an act authorising the formation of a cadet system, by which young men could be trained to discharge the duties of third lieutenants. By this system, young men between the ages of eighteen and twenty-five became candidates for a strictly competitive examination in arithmetic, algebra, geometry, trigonometry, physics, chemistry, grammar, composition, rhetoric, history, geography, literature, either German, French or Spanish, and general information.

Those who stand the highest are selected for appointment as cadets, and are ordered to report on board the practice ship *Chase*. The course of instruction on this vessel is devoted almost entirely to subjects of a technical character, such as seamanship, navigation, and international and customs laws. The *Chase* is, for a large portion of the time, kept constantly at sea, where the cadets are compelled to take an active part in the handling of the vessel. At the close of the two years' course, they are subjected to rigid physical and professional examinations, and, if found qualified, are then commissioned as third lieutenants, and are in line of promotion to higher grades.

The present chief of the revenue cut-

ter division is Captain Charles F. Shoemaker, who began his career as a naval cadet at Annapolis, but resigned to enter the revenue cutter service in 1860. He served during the Civil War on board the cutters stationed on guard duty at New York Harbour. Appointments to the Engineer Corps of the service are made directly from civil life, and the fitness of candidates is determined by very exacting competitive examinations. The requirements have recently been onometry, geometry, mechanics and physics, electricity, chemistry and machine-designing. Questions are given which require a thorough knowledge of the various types of marine engines, boilers, condensers, screw-propellers, and indicators, their care and management, the prevention of accidents, and the various methods of repair.

At the suggestion of the writer, graduates in mechanical engineering from technical institutions, notably from Cor-



THE "PERRY"

increased so that the majority of appointments are now made from graduates of technical schools and colleges. To be eligible for an appointment a candidate must be between the ages of twenty-one and twenty-eight years, a citizen of the United States, and physically robust. He must have served not less than six months in the engine-room of a sea-going vessel, and be either a graduate of a full four-years' course in a technical school, or have served eighteen months in a machine shop. The professional examination includes grammar, composition, arithmetic, algebra, including the use of logarithms, trig- nell University, Stevens Institute of Technology, the Massachusetts Institute of Technology, and the Kentucky and West Virginia universities, after successfully passing the prescribed examinations, have been made eligible for appointment as second assistant engineers. This has resulted in bringing into the service some highly accomplished young men.

The personnel of the revenue cutter service consists of 215 commissioned officers (one hundred and forty-four line and seventy-one engineer officers) and an enlisted force composed of petty officers, seamen, oilers, firemen, and

others aggregating 1000 men. By act of Congress, approved March 2, 1895, forty-one officers, representing all grades, were placed on a "permanent waiting orders list," owing to physical disabilities incurred in the service. This virtually provided a limited retired list, differing only from those of the army and navy in the matter of pay. While army and navy officers receive three-quarters of the highest pay to which their rank at time of retirement entitles them, their less fortunate comrades of the revenue cutter service receive only one-half of their active duty pay, which, at the best, is far less than the corresponding pay of naval and military officers.

As the officers of the revenue cutter service are exposed to as many, if not more, hardships and dangers, it is manifestly an injustice to them that they are deprived of the benefits of a retired list when they become physically incapacitated to perform active duty, either from the weight of years or from sickness or injuries incurred while in the service of the government. Not alone is it an injustice to those incapable of performing duty, but it is decidedly detrimental to the efficiency of the service, inasmuch as it prevents the advancement of younger and more active officers who cannot be promoted until deaths occur in the higher grades. Bills to remedy this evil by providing a permanent retired list are pending in the Senate and House of Representatives at the present time.

Another injustice that is working against the interest of the revenue cutter service is the law which provides that the officers and seamen of this service who are wounded or disabled in the discharge of their duties "while co-operating with the navy" may be placed upon the naval pension list. Why this discrimination exists against those who become disabled or wounded in the service of the government through the perpetually dangerous and military character of their vocation in times of peace, is matter of question to every justly thinking mind. The ordinary duties devolving upon the revenue cutter service are fraught with greater risk to life and limb than those incurred by the army, navy or marine corps in time of peace, while, in time of war, the dangers and hardships are shared equally by all who take part in it. Every argument, therefore, which justifies the extension of a pension to members of the army, navy and marine corps, applies as forcibly to the officers and enlisted men of the revenue cutter service.

It is many years that this branch has laboured without hope of meeting with consideration for its infirm, disabled or wounded members, or of any provision being made for the widows and orphans of those who die from prolonged exposure to the extremes of heat and cold, from epidemic diseases which they are required to face, or from petty battles provoked with illicit trading vessels by enforcing the authority of the Secretary of the Treasury, and a strict observance of the customs laws. What a stimulus to ambition in the ranks of the cutter service would ensue were simple justice done!

That the service is ever prepared for special duties of all kinds and at all seasons has been attested throughout a century. Whether engaged in patrolling the icy waters of Bering Sea, or guarding the seals' breeding grounds on the Pribilof Islands; in skirting the coral reefs of Southern Florida to enforce neutrality; or cruising in perilous proximity to the coast and on the treacherous waters of the Great Lakes to warn and assist ships out of danger; in helping the government quarantine officials to maintain a military cordon by sea around some plague-stricken section, or in making those routine trips which sometimes result in conflicts with smugglers and mutineers on merchant vessels,—the vigilant revenue cutters are constantly on the alert and fully warrant their official motto "*Semper paratus.*"

ANCIENT MINING

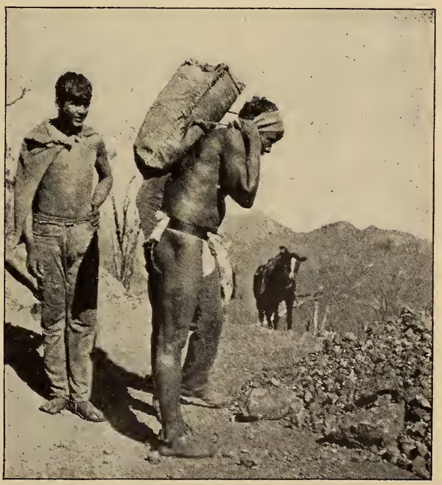
By Dr. John A. Church, M. Am. Inst. M. E.

AN AFRICAN WOMAN WASHING GOLD-BEARING GRAVEL

THE art of mining is so very old that we have no means of estimating, and no ground even for conjecturing, where it began. The place we may assume with much probability to have been that part of Asia which the concurrent results of many lines of investigation indicate as the starting point of our race.

We also believe, and on very good grounds, that the first metals known were those which occur native, or in the metallic state,—gold and copper,—and it is highly probable that gold was the first metal known to man It is found in sands, mostly as a metallic dust, but sometimes in the form of pebbles, called nuggets. There is evidence that the discoverers of these nuggets knew them only as malleable stones, and that they were utilised by beating out the cold native metal for some time before the value of fire as a means of changing their shape was known. Articles of copper, made in this way, are found in all countries. Even some of the iron ornaments of Egypt were so made; analysis shows the presence in them of nickel,—a metal unknown to the ancients. It is not found with any ore of iron they could treat, but it is a constituent of some meteorites, and there is no doubt that these iron ornaments are derived from "falling stars."

The late Sir Henry Bessemer, who laboured for years to discover some method of giving to copper or bronze that high temper which, according to ancient writers, was known to the Egyptians and other historic nations, reported that none of the resources known to modern metallurgists would produce copper tools of sufficient hardness to serve for cutting the hard granites which were used so abundantly for Egyptian buildings, and which were covered with deep-cut hieroglyphics. He confirmed the suggestion made by the Egyptologist Wilkinson, that "meteoric steel" tools were in more common use than is now supposed, and that the fall of meteorites may have been more abundant four or five thousand years ago than now. These conditions of the Stone Ages are repeated in our own day for Nordenskiold found that the natives of Greenland resorted to some large meteorites for material from which to make spear points and similar articles. Still, the production of such tools does



A MEXICAN ORE CARRIER

not establish an advanced era of mining or metallurgical knowledge.

It is well settled that there was a time when the distinctive character of metals was absolutely unknown, and the only implements in use were made from stone, bone, wood, horn, and other similar materials. If a metallic nugget was found there was no comprehension of its essential difference from other stones. This condition ended with the discovery that fire would turn metal to a fluid and thus afford a means of uniting separate grains and nuggets into one mass.

The most ancient traditions profess to account for the discovery of fire which they ascribe to instruction by, or

GOLD WASHING IN JAPAN

gift from, the gods. May not these traditions point to the discovery of the fact that heat will fuse metals? It is difficult to imagine that a time ever existed when man was ignorant of fire. Certainly he was not so immature in the Stone Age, for remains of that period have preserved embers and other proofs of the use of fire.

The first mining probably consisted in digging up the sands of gold-bearing streams and washing them in a current of water so graduated as to have force enough to carry off the light particles of earthy sand, but leave the heavy gold behind. A grain of gold is six or seven times as heavy as a grain of ordinary quartz sand of the same size; but in spite of the margin of safety that this great difference affords, it is probable that the early miners lost, in washing, about half the gold in their sands.

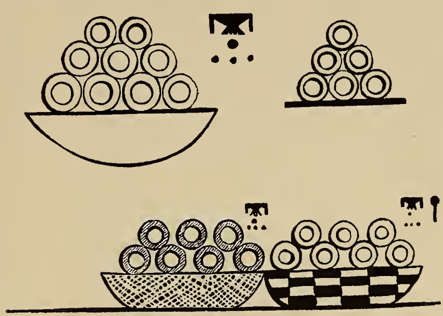
Although this method of mining is so very old, it is practiced in our own day in precisely the ancient manner, and not only by half-barbarous nations, but by a people so highly civilised as our own. It was in this manner that the great yield of gold was obtained in California in the '50's, and it is still in use there to some extent. In the Klondike region, at present, no other method is used, and the last discovery in the mining world touches hands with the first over a space of time of which we know no more than that it covers many thousands of years.

The art of washing gold sands is now elaborate and complex, but in countries like China and Japan we find it carried on in a simpler form, though, undoubtedly, far advanced beyond the first crude methods. By the courtesy of Prof. Munroe, of Columbia School of Mines, the writer is able to show some illustrations of Japanese mining taken from an old native book. The little annexed sketch represents a view of gold washing. In one corner is a hand mill for grinding the ore; below it is the table on which the sand is washed by a stream of water, and in front of it are tubs in which the concentrated sands receive their final cleaning.

The writer has seen this simple machinery in use in China. The table, a light platform of boards, about six feet long and two feet wide, is laid on the bank of a stream, care being taken to have it quite level in the narrow direction and sloping gently in the direction of its length. Water is brought by a ditch to the high end, or "head," of the table, and is distributed evenly over the whole width. The gold sand is thrown upon the high end, and the current of water washes the sand down and away, leaving on the table all the heavy material. This consists of a black iron sand, and, as this deposit accumulates, it is carried down the table, and if allowed to go on, would, in part, reach the lower end and be lost. To prevent this, the workman pushes it back toward

the head of the table with a wooden shovel.

At length, by repeated washings, the light sand has all been washed away, leaving nothing but black sand and gold. Much of the black sand is magnetic iron ore, and the Chinese miner



EGYPTIAN GOLD AND SILVER RING MONEY

takes a piece of the same iron ore, which he knows by experience to have strong polarity, and uses it as a magnet to lift out the magnetic grains. The remainder is washed carefully in a wooden shovel or scoop, leaving the clean gold.

While this process is, undoubtedly, very old, we cannot imagine that it was employed from the first, for the use of the magnet is a refinement that probably came after long experience, and is unknown, even at the present day, to people less advanced than the Chinese. At first the gold was cleaned entirely by repeated washings. This implies very great skill in manipulation, for the cleaning of gold from heavy iron sand is a really difficult operation; but we find that barbarous tribes are very expert in this work.

By the examination of ancient workings and by observing the methods employed at the present day by uncivilised tribes, and joining to these some historical notices, we may learn what may have been the steps of progress in the art of gold washing, the simplest, and probably the most ancient, of all mining operations.

Herodotus tells us that Darius required from the Ethiopians a triennial tribute of two chenix, or three pints, of unrefined gold. As the chenix is a dry measure, the gold was probably in the form of dust, and from other conditions of the tribute exacted from these people, it is supposed that the value of the gold was small, and, therefore, unrefined gold may mean the black gold-bearing sand,—an indication that the Ethiopians did not know how to separate the clean metal, though they could wash off the light sand.

In the Khanate of Bokhara, in Central Asia, the inhabitants are now washing gold from sands in the old rude way, and their work is instructive because it shows ignorance of two important facts. First, their ore contains clay, which is not dissolved by the water, but rolls off, carrying an important quantity of metal with it. The sand also contains pebbles which carry gold, and these are lost, for the Bokharans have not advanced so far as to crush ore. They get only the loose gold in the sands, and they are in a very rude state of mining knowledge.

Mungo Park, in his "Journal of a Mission to the Interior of Africa in the Year 1805," tells us that the Africans living on the rivers of Northern Africa wash gold sands in wooden bowls, and, after getting the gold, they

ANCIENT METHOD OF WEIGHING RING MONEY

make a crucible from common clay, dry it in the sun, and melt the gold in it without flux or cover of any kind. The melted metal is poured into a small furrow, traced in sand, making a rough bar. This is beaten to a square shape,

PROSPECTING FOR ORE WITH THE DIVINING ROD THREE HUNDRED YEARS AGO.

reheated, and drawn out by forging, and finally bent over to form a massive ring. The value of their work as an example of very ancient mining, is shown in the fact that on Egyptian monuments we find pictures of this "ring money" in piles, with a weigher weighing it in scales, and a scribe recording the weight.

We may well assume that this represents the most ancient mode of utilising the washed gold. Similar rings are found in the barrows of the ancient Britains or Druids. Mungo Park's sketch of a woman washing gold sand is reproduced at the head of this article; the lower illustration on the preceding page is from an Egyptian mural painting, and shows "ring money" weighed against weights in the shape of lambs. When Abraham bought a field for the burying place of his wife he paid for it in "lambs" of silver.

The methods of the Chinese show us the full development of prehistoric gold working. They are more advanced than the Ethiopians of Darius' time, for they know how to clean the gold from the black sand; more advanced than the Bokharans, because they mine the solid vein and crush the rock before washing; and more advanced than the Niger Africans, because they melt their gold with flux. It must have been by successive steps like these that the art of mining was gradually carried from its first and simplest stages to the really complex development in which we find it at the dawn of history.

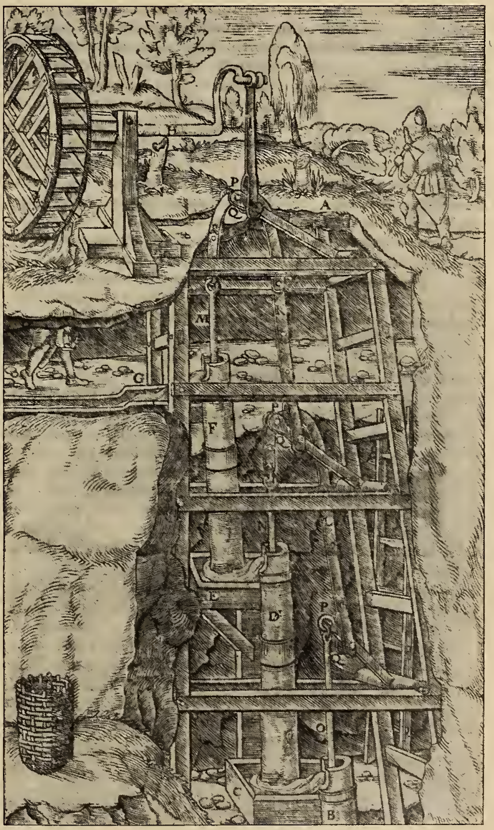
"The earth," says Job, "hath dust of gold;" and elsewhere he says, "There is a vein for the silver and a place for the gold where they fine it," *i. e.*, clean it from the sand in which it is found. These expressions, though so concise, are perfectly correct descriptions of the distinctive occurrence of gold and silver ores, and they indicate that one of the most learned and accurate writers of the ancient world,

living, perhaps, 900 or 1000 B. C., was not acquainted with the fact that gold also occurs in veins. If he did not know it, we may be certain that such knowledge was not general in his day, though this does not prove that vein mining for gold was not carried on anywhere at that time; for it is equally certain that improvements and discoveries in mining, made in quarters distant from the centres of learning, may have remained matters of entirely local knowledge for centuries. In our own day we find gold mined in Central Asia by methods much more crude than were practised in South Africa in times that are supposed to be of about Job's date.

The old workings in South Africa give us a clear idea of the limitations of the ancient miners. Their only knowledge of gold was as a visible metal,—the native gold. The outcrops of their veins contained the metal in this form; but deeper down in the veins, though the ore is still rich, it is so combined with the common mineral pyrite (iron sulphuret) as to be invisible. Their work stopped when this mineralised conditionof the metal was reached, for their knowledge did not extend to the point ot recognising the value of such ore and extracting its metal.

The methods by which the earliest mining in veins was done are known to us by the evidences of the aboriginal mining for copper at Lake Superior, in the United States, and for gold in South Africa. At Lake Superior great masses of native copper were found projecting above the surface of the ground, and the mound builders dug holes at such points, pounding the rock away with stone hammers until the metal was exposed, when the projecting points of copper were broken off in the same way. There is no evidence that chisels or other tools of copper were used on the rock, and the only implements of the miner were stone hammers, wooden shovels, and perhaps bags of skin or baskets to carry out the broken rock.

The method in South Africa was precisely the same, with two important additions. The Africans seem to have known the use of metal tools for working in the soft ground, and remains of small furnaces are found which appear to have been used for sharpening these tools. After digging out the soft rock and exposing the hard vein, they broke the ore down with heavy stone hammers, and aided this work materially by the use of fire.



AN ANCIENT MINE PUMPING PLANT

When rock is quickly heated by a hot fire it cracks and splinters, and is more readily broken afterwards by hammers. The Africans knew this, and employed it in their work. This was an important advance in the art of min-

VARIOUS WAYS OF ENTERING A MINE

ing. It came into use over the whole world and was employed in Europe in the last century, and perhaps even in this, and within thirty years an English inventor proposed to revive it, and brought out a portable furnace for doing the work; but the method has given way completely before the great advantages that result from the use of powder.

This method of mining by "fire-setting" is shown in one of the illustrations in George Agricola's work, published in 1561. In this is shown also the method of prospecting for ore by means of the witch-hazel rod,—a simple superstition that is firmly rooted in the minds of thousands to this day. This illustration is reproduced on page 392.

On the opposite page is reproduced from the same book a picture of several methods of entering a mine, *i. e.*, by a ladder, by sliding down a rope, by lowering with a windlass, and by walking in through a tunnel where the head of a horse hints at the means of transport.

Among Japanese data we find references to appliances of a still simpler state of mining, the notched log being a kind of ladder that was probably the only artificial means of egress for thousands of years, a square wooden pump, and an ore basket, arranged for slinging from the shoulders. These baskets are replaced in Mexico by rawhide bags, shown on page 389, which represents two sturdy "tanateros." These men carry loads of 160 to 220 pounds, and the remarkable efficiency of the human frame is shown by comparing these weights with the regular load for a mule, 300 pounds.

Another method of getting ore from the mine was by the familiar windlass. Agricola shows us the means by which the early attempts at deep mining were made. Steam was unknown as a power, and the waterfall was the only substitute for human and brute strength.

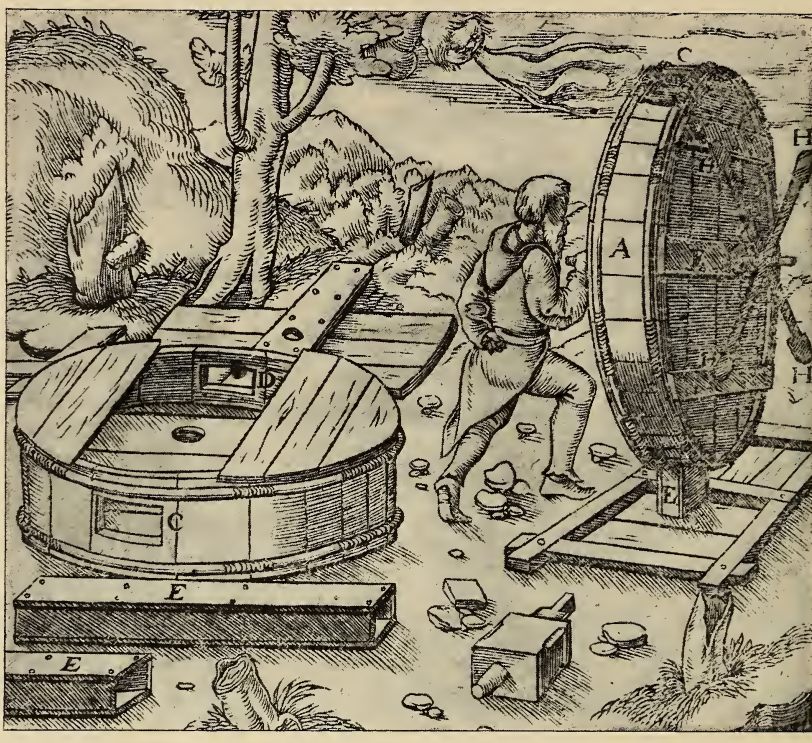
The illustration on page 393 shows how water was pumped from one level to another in the mine, and finally to the surface through wooden pipes by means of a water-wheel on the surface.

The application of power was not confined to the surface. When a mine could be drained by a tunnel, water from a surface stream was led into the shaft, and, falling from wheel to wheel, underground, operated various devices on its way. On page 396 is shown a fan for ventilation; and in the illustration above a chain pump.

A CHAIN PUMP OF THE SIXTEENTH CENTURY

Besides gold and copper, the Bible mentions silver, lead, tin and iron as metals known at the time of Moses. Gold and tin are found in sands; iron often occurs in large surface outcrops; but the others are obtained exclusively from veins. All but gold and copper occur only in such combinations with oxygen and sulphur that their metallic character is completely masked.

The language used in the oldest records indicates that these metals were



AN ANCIENT MINE VENTILATING FAN

not rarities, and we must conclude that more than 4000 years ago they were in such common and extensive use that the date of their discovery is necessarily thrown back to a much earlier period, —probably several thousands of years earlier. The interval between the discovery of these ores and the wide development of mining at the time of Abraham is not only prehistoric, but pretraditional.

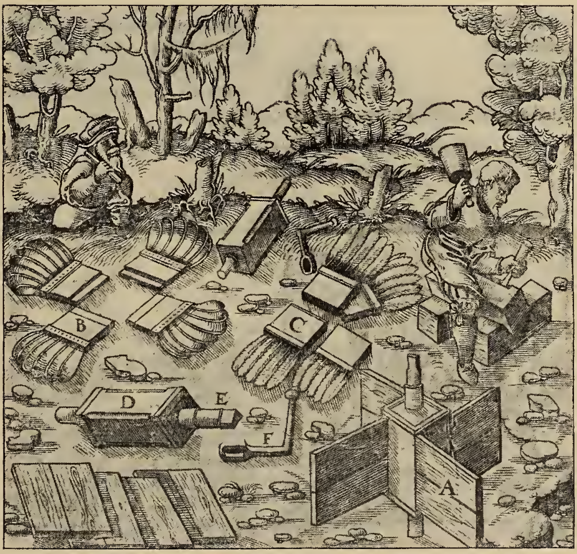
The art of mining was very widespread among the ancients, and was practised in every country of the old world, from Africa, India, and Asia to England, centuries before our era; and it is known that work in metals had reached a high development in the East twenty centuries before the Christian era. Stories that appear marvellous are recorded of the ancient accumulation of gold and silver. In Babylon there were three great statues of beaten gold, two of them 40 feet high, and the third probably of similar dimensions, though sitting. Besides these there was an altar, 40 feet long and 15 feet broad, covered with gold plates and several massive bowls and censers. From the weights given, it has been calculated that the raw metal in these constructions weighed about 2,700,000 ounces, and would now be worth $55,000,000, or about £11,000,000.

When Darius divided the Persian Empire into satrapies, he required from them a yearly tribute amounting to between thirteen and fourteen million dollars. The accumulation of gold by David and Solomon for the decoration and furniture of their temple was very great, and we have the remarkable statement that silver was so common as to be "nothing accounted of in the days of Solomon." Inasmuch as the extraction of silver is incomparably more difficult than that of gold, it follows that the arts of mining and metallurgy had

reached a high point long before the date of that monarch.

The credibility of the historians who give us these records of great accumulations of metal has often been attacked on the ground of extravagant statement; but when we remember that gold did not then enjoy the current use it has now, and was, to a great extent, concentrated in the hands of powerful kings, the writer sees no reason for discrediting the classical writers. We have in the China of to-day an indication of the position which gold must have held in Babylon and other countries of the ancient world.

China produces from two to six million dollars' worth of gold yearly, or from 100,000 to 300,000 ounces, and it has but very limited use for the metal. Chinese art does not value it highly; the rich wear it only to a very small extent, and if it were not for the foreign demand there would be a constant and increasing accumulation of the useless metal in that country. In a century the



MAKING A VENTILATING FAN WITH FEATHERED VANES

stock of gold in China would be greater than any of the great treasures mentioned in history, and if the Chinese liked that sort of art, they could have golden statues greater than those of Babylon. Remembering that the treasuries of

ONE OF THE GREAT JAPANESE STATUES OF BUDDHA, FORTY FEET HIGH

kings and the metal collected in cities would pass to the conqueror when defeat came, as it did come to every nation of the past, every decisive war would be the cause of a new concentration of golden wealth. Thus the gold accumulated by the Jews during 800 years, and added to by the expeditions of Solomon, went in one great spoil to swell the holdings of Nebuchadnezzar.

Crude as the ancient methods were, they resulted in a very extensive industry. China produces to-day nearly a half-million tons of iron, not only by the crudest methods of mining, but often without a furnace, most of this great product being made in crucibles that contain only one and one-half pounds each, and their work illustrates the essential difference between the old mining and ours.

The quantities given show that the Chinese must use about 350,000,000

crucibles yearly, and the great results of ancient mining were all obtained by the multiplication of small units. Now, by the use of steam, our mines yield thousands of tons each day, and one

SOME JAPANESE MINING METHODS

furnace, producing 500 tons of iron in a day, does the work of 250,000,000 Chinese crucibles.

Japanese pictures give us a good illustration of mining in the day when it was carried on entirely by human labour without assistance from other power. In the little sketch above we see a miner wielding a huge hammer to drive a wedge into the rock, and another working with a single hand hammer. Chipping the rock away in this manner was, with the exception of fire-setting the only method of mining for thousands of years until the introduction of gunpowder two or three centuries ago, and elaborate lectures upon it were delivered in mining schools within this half century. The illustration also shows a hand pump and an ore carrier with his basket.

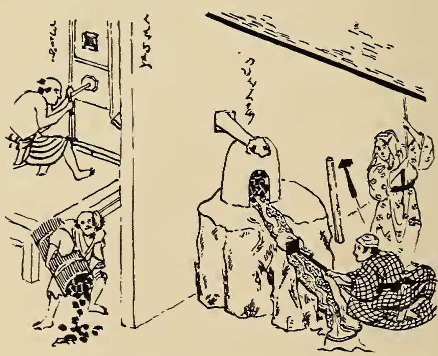
The ancient operations of metallurgy are well shown in the adjoining cut, where men are seen smelting copper ore in a small furnace. The latter, two feet high, is characteristic of barbaric work to this day. The man seated is pushing the piston of the air-blowing machine, made of a square wooden box, in which works a piston made sufficiently tight by feathers.

The same construction was used in Europe, and Agricola shows us, in the cut on page 397, a man making a fan with feathered vanes. The great results which can spring from the multiplication of these small units of production are illustrated by the Bonze, a great statue of Buddha, 40 feet high, shown on the preceding page.

The number of men employed by the ancients in mining must have been very great, and the influence of this industry upon human life and happiness was so important that even to our own day mining has not recovered from the ill repute which brutality and greed once gave it.

The old mines were horrible working places. The galleries were low, tortuous, so poorly supported that accidents by caving of the roof were probably frequent. They were lighted by pine knots or by lamps, made only of a clay saucer filled with ill-smelling vegetable oil or tallow, in which a bit of rush, pith, or rag, floating, served for wick; and they were without ventilation to carry off the dense smoke from these lamps and the effluvia arising from severe labour. Even after centuries of experience, when mining had become a great industry, the condition of the miner was deplorable.

When deep mining began, his labour became still more severe, for all the products, water as well as rock, were



ANCIENT METHOD OF SMELTING COPPER ORE

carried out at first on the men's backs. The introduction of machinery brought no alleviation, for it was worked by man power.

Water was raised from level to level

A TREADMILL OF AGRICOLA'S TIME

by the treadmill,—a machine which found its last use in prisons for the discipline of convicts, and now is rarely employed, even for animal power. The remnants of treadmills have been found in Spanish mines and in Spanish America, and they are figured in German books as one of the means of hoisting four centuries ago.

A treadmill of small size is shown in the cut on this page, reproduced from Agricola. Larger forms were built like water-wheels, with rungs in place of buckets, and a gang of men, climbing from rung to rung, afforded by their weight the power that is derived from water in wheels adapted to its use.

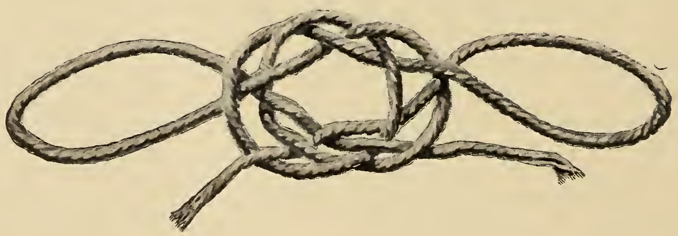
If we may judge from the existing conditions in China, the miners were miserably fed. The labour in the mines was compulsory, the Egyptian kings condemning to the mines not merely captives taken in war, and criminals, but even persons falsely accused and those who had offended the king, the *personæ non gratæ* of whom we sometimes read now in diplomatic correspondence, and not only the principals, but all their kindred. In Greece the mines were worked by slaves, who were hired at the rate of seventy-five cents a month per head, and we read of 2000 and 3000 slaves employed by one mine owner.

All the indications are that the miner, as we know him, a freeman, working for good wages, proud of his skill, and with his safety guarded by careful laws, was a being unknown to the ancients. Those who were unfortunate were

herded with criminals and driven to the mines, where they laboured night and day, ill or well, under the most unwholesome conditions, naked, guarded by merciless soldiers, flogged and treated with a cruelty that no slavery of which we have experience can measure.

When the Phœnicians established trading colonies in Spain, they are said to have compelled the inhabitants to work the mines, and when the natives were killed by the cruel labour, slaves were brought in from Africa. It is recorded that Hannibal won the good will of the Spaniards 200 years before our era by showing them how to work their mines, which probably means that he corrected these cruel conditions to some extent.

We may well imagine that the constant references in literature to money as the root of all evil are not confined to the moral effect upon its possessor, but embody, in part, the lesson of brutality and suffering which the unfortunate miner had to endure to win gold for his master. Even to this day mining appears to the uninitiated to be a hazardous, fearsome occupation, though to-day, in civilised countries, hundreds of thousands of men go daily to comfortable and intelligent work and return from it in safety. Instead of getting our metals by forced labour, it is acknowledged by all observers that men who have once learned this art will not leave it for farming or other pursuits.

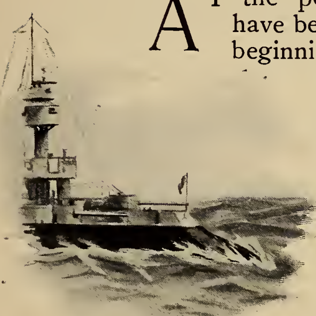


THE OUTLOOK IN MARINE ENGINEERING

By Commodore George W. Melville, Engineer-in-Chief of the United States Navy

PART II.—DESIGN OF MACHINERY, AUXILIARIES, THE STEAM TURBINE, LIQUID FUEL AND THE PROPELLER

Part I. Appeared in the February Number



AT the period which we have been taking as the beginning of our survey, the marine engine was very heavy for the power developed. This was due to four causes,—the low steam pressure carried; the low piston speed and rate of rotation; the low rate of combustion in the boilers; and the inferior quality of the materials used, as compared with what obtains to-day. The engine was also a very complex machine. For the purpose of securing varying grades of expansion, ingenious but complicated cut-off mechanisms were employed; all the pumps were worked from the main engine; and there was a tendency to run to very intricate castings about the condenser and pumps. This state of affairs did not diminish with the introduction of the compound engine at first, but toward the close of the compound period there was a decided improvement all along the line, due to increase of pressures, increased rotational speeds, and to better material. As has already been stated, the possibility of the successful use of the triple-expansion engine was due to the improved material for boilers.

With the increase in steam pressure, and the number of stages of the expansion, there was an increase of simplicity, due both to the fact that the complicated mechanisms would not work so well under the higher pressures, and that they were no longer necessary, inasmuch as the cylinder ratios themselves provided a sufficient expansion, and any variation needed was secured by the link.

In naval practice one of the greatest improvements was the increase in rotational speeds, which caused a material reduction in weight, and this increase has continued steadily up to the present time. With these fast-running engines it was not so easy to work the pumps from the main engine, and they were gradually made independent until the best naval practice of to-day is to leave for the main engine nothing to do but drive the propeller, the condenser being entirely separate with its pumps, and all other pumps also being worked independently. This has, of course, had its drawback in the fact that the economy of these small engines, which are either simple or compound, is very much less than that of the main engines, and, indeed, the wastefulness of the auxiliaries has become a serious problem. This will be discussed more fully under another head.

Although forced draught for increasing the rate of combustion was used in the United States Navy during the Civil War, it did not come into general use for naval vessels until about 1882, and in the merchant service still later, but since that time its use has become universal. Indeed, were it not for forced draught, boiler weights would be so great as to have long ago set a limit to speeds of the faster classes of vessels. When natural draught alone was used, the maximum rate of combustion with the best free-burning coal and good chimney draught did not reach 20 pounds per square foot of grate. With forced

draught in large cylindrical boilers there are now numerous reliable records of 40 pounds per square foot, while in locomotive and water-tube boilers 80 pounds is now a common rate, and data have been published of over 100 pounds.

While the economy of evaporation at these high rates of combustion is not so great as under natural draught, the enormous reduction in boiler weights is very marked. The trials of the boiler of the United States torpedo-boat *Cushing*, for example, show an increase in I. H. P. per ton of boiler of over 50 per cent. when the rate of combustion is increased from 24 to 40 pounds per square foot of grate, which means a decrease in weight per I. H. P. of over 33 per cent.

Except on Mr. Howden's part, the question of economy under forcing was for a long time ignored, designers being content with the great gain in power. At the present time, however, the question of economy under forcing is receiving great attention, and we may confidently anticipate this as one of the features of progress.

The improvement in material has been very marked, and this has, indeed, enabled the higher pressures and higher rotational speeds to be adopted with safety. At the beginning of the period wrought iron was the main reliance of the designer for all parts requiring considerable strength, and, as is well known, the process of manufacture left much to be desired on the score of reliability. When mild steel was introduced and sufficient experience had been gained to show its entire reliability, the progress was rapid.

The wrought-iron boiler plates had a tensile strength of about 50,000 pounds per square inch, and never exceeded an inch in thickness, while it is now easy to get steel plates an inch and five-eighths thick, and with a tensile strength of 67,000 pounds per square inch. As shown by the last report of the Engineer-in-Chief of the United States Navy, carbon steel plates have been produced with a tensile strength of over 74,000 pounds, and thoroughly satisfactory in all other respects; and nickel steel plates with a tensile strength of 90,000 pounds, have also been made and used in the boilers of the United States cruiser *Chicago.*

The engine forgings, such as connecting and piston rods, valve stems and shafts, formerly used, had a tensile strength of about 50,000 pounds, while for a number of years mild steel forgings have been obtainable, with a tensile strength of over 65,000 pounds, much greater elongation, and absolutely homonegeous and satisfactory in every way. At the present time, nickel-steel forgings, oil-tempered and annealed, are turned out daily with a tensile strength of over 95,000 pounds, 65,000 pounds elastic limit, an elongation of more than 21 per cent. in 2 inches, a reduction of area of about 50 per cent., and a fine silky fracture.

At the beginning ot the period steel castings were unknown. They are now a very important feature in the structure of a marine engine, and while absolute perfection has not yet been reached, still, in a general way, they may be said to be entirely satisfactory. At the present time there is no difficulty in obtaining castings which give a tensile strength of 65,000 pounds, with an elongation of 25 per cent. in 8 inches.

Whereas formerly ordinary bronze, with a tensile strength of 23,000 pounds, was used almost exclusively, and white metals for the bearing surfaces were unknown, at the present time manganese and the other strong bronzes, with a tensile strength up to 70,000 pounds per square inch, with 30 per cent. elongation in 2 inches, are now common, and the use of white or anti-friction metal for bearing surfaces is universal.

Copper, which was formerly universally used for piping, has, in recent years, begun to fall into disfavour for certain purposes. At the high pressures now carried, the temperature is such as to cause a material reduction in the strength of copper, and the thickness necessary for large steam pipes has made their manufacture uncertain. This has led, in the United States Navy, and in some of the more recent merchant vessels, to the substitution of seamless

drawn or lap-welded steel pipes, with forged steel flanges welded on, for the larger pipes, and in the latest specifications of the United States Navy for torpedo-boat destroyers, steel pipes are used for all diameters above two inches.

There has also been a great deal of trouble with copper pipes for supplying salt water, which has been attributed to a number of causes. A favourite theory is that the deterioration or corrosion is due to electrical action, but the evidence of this is so far from conclusive that many engineers believe that the corrosion is due to soluble impurities in the copper. An effort is being made to prevent this corrosion by coating the interior of the pipes with a protective varnish, and also by the use of zinc boxes, which are composition boxes, placed at intervals along the pipes, containing slabs of zinc, the idea being that an electric circuit will be formed, in which the zinc, being the most electropositive of the metals in the circuit, will be the one to be attacked.

At the beginning of the period, all the engines of war vessels, and nearly all of those in the merchant service, were horizontal, but the overhead vertical-cylinder engine soon became universal in the merchant service, and in recent years it has also become universal in naval practice. The limitations of war vessels have compelled the use of much shorter strokes than in the merchant service, but this conforms to the necessity for quick-running engines, which contributes to reduced weights.

The latest feature in the design of the engine has been the care to so arrange the cylinders and crank angles as to reduce vibration to a minimum. As long as the piston speeds were low, the inertia stresses set up were not great, and the vibration was not a serious inconvenience. With the increase of speeds, vibration has become a question of considerable importance. The ordinary three-cylinder, triple-expansion engine suffered from this defect; but the investigations of Mr. Yarrow, in England, and of Mr. Schlick, in Germany, showed simple and effective means of obviating the difficulty.

Mr. Yarrow's original plan was by the use of weights specially located, and Mr. Schlick's by the arrangement of the engine with four cylinders. What is now known as the Yarrow-Schlick-Tweedy system of balancing, contemplates four cylinders, specially arranged to make the inertia couples as small as possible, and with the crank angles specially arranged to reduce the inertia forces to a minimum. Many designers, however, have rested satisfied with the adoption of the four-cylinder type (which has other recommendations) and the arrangement of the cylinders so as to reduce the inertia couples, but with the cranks at right angles instead of at the special angles necessary in the system just mentioned.

In boiler design it has already been shown how progress has occurred, and it may be said that the cylindrical boiler is to-day practically as perfect as it can be made, and that, while it is still the type almost universally used in merchant steamers, the water-tube boiler has practically superseded it for naval vessels, and seems destined to do so in the merchant service.

From many points of view there are numerous makes of water-tube boilers in use to-day which are entirely satisfactory, but thus far it has seemed that the boilers which were most satisfactory on the score of lightness and economy, left something to be desired from the standpoint of facility of overhauling, cleaning, and renewal of parts. On the other hand, most of the straight-tube boilers, which are the easiest to clean and to overhaul or repair, have been heavier, and, at least as installed, have had the great objection of numerous units for the same power. This last is a very serious objection, as it means an enormous amount of work for the boiler attendants, even with automatic feed service, and also a greatly increased number of fittings and mountings. Colonel Soliani expressed this very wittily at the International Engineering Congress in 1893, by saying that it was much easier to drive four big horses than sixteen ponies. The special advantages of water-tube boilers have been so thor-

oughly discussed of late that it is unnecessary to go into the subject at length here.

The outlook for the future with regard to design of machinery would seem to be that the type of engine is likely to remain the same as at present, inasmuch as the progress in recent years has been almost entirely in matters of detail, unless, indeed, the steam turbine should cause a complete revolution, and of this there does not, at present, seem a strong probability. For the boilers, in the writer's opinion, it is almost certain that the water-tube boiler will entirely supersede the cylindrical. As to exactly which form of water-tube boiler will become the common type, it is very difficult to say. The writer's own opinion inclines toward the view that the water-tube boiler which will survive will have straight tubes of moderate diameter. It seems almost certain, as has already been stated above, that heated draught and feed heaters will be essential features of this water-tube boiler, whatever the exact form of the latter may be.

Table III. on pages 406 and 407 shows the progress in steam pressures, revolutions, and reduction of weight of machinery per unit of power.

Auxiliaries

As was stated previously, the problem of the economy of auxiliaries has become a very important one, as the aggregate horse-power of the auxiliaries on a large ship is now considerably more than the horse-power of the main engines of good-sized vessels of twenty years ago. A paper by P. A. Engr. W. W. White, U. S. N., published last year, set forth the facts in regard to the steam consumption of all the auxiliaries of one of the finest war vessels in the world,—the U. S triple-screw cruiser *Minneapolis*,—and this is, undoubtedly, a typical case. As shown by that paper, the steam consumption of almost every auxiliary engine on the ship was high, while of some it was enormous.

Various solutions of the problem have been proposed. One is to have a sort of central pump station where a very economical triple-expansion engine would furnish the power, and all the pumps would be driven by it.

Another is to make the cylinders of the auxiliary engines, in effect, a part of the intermediate cylinder by having them take their steam from the first receiver, and exhaust into the low-pressure receiver. For merchant steamers which make long runs under absolutely uniform conditions, this would seem to be a very satisfactory solution; but for naval vessels, in which facility for manœuvring is so important, even if this were adopted, it would be necessary to have an arrangement of valves, readily changeable, to throw the pump cylinders out of the circuit and have them take steam from the auxiliary steam pipe and discharge to the condenser.

Another plan is to compound all the engines which have hitherto used steam with only one stage, and that really without expansion at all. This would, undoubtedly, materially increase the economy, but in some cases it would, undoubtedly, increase the weight.

Still another solution is the use of electric motors for driving nearly all the auxiliaries. The advantage claimed is that the efficiency of both motors and generators is so high that their combined losses will reduce only slightly the benefit to be derived from supplying the power for the generator from a very economical engine rather than having a small steam-engine to drive each auxiliary.

This last solution is one which has been applied to some extent for such auxiliaries as hoists, winches, and turret-turning gear, and, as far as the working of the auxiliaries is concerned, the result is entirely satisfactory. There are also certain facilities for installation and handling which commend this system above that of small steam-engines located at a considerable distance from the boilers. The problem, however, is a difficult one, and, for its thorough solution, requires more investigation and analysis than many writers have given it.

Even more important than the economical development of power are the

items of reliability and adaptation; and the questions of weight, space occupied, and first cost must also be considered. For instance, from many points of view it would seem that the capstan and steering engines afforded examples where the electric power would have great advantages on the score of facility of installation; yet many strong advocates of motors for other purposes oppose them here on the ground that electric apparatus is not sufficiently reliable for these important places.

Again, from some considerations motors would seem specially adapted to the forced-draught blowers, but when we reflect how rarely these are used on naval vessels, and that the electric plant to run them (including engines and dynamos) will weigh more than three times as much as steam-engines, and probably exceed the cost in a still higher ratio, it becomes nearly certain that it would be far from economical to install motors for this purpose. These illustrations are given to show that it would be unwise to be stampeded into using electric appliances everywhere because they are the best for certain situations.

Mr. George W. Dickie, the talented manager of the Union Iron Works, of San Francisco, has suggested that the solution of the problem could best be determined by taking several ships of absolutely identical design otherwise, and fitting them with different systems of driving the auxiliaries, but having all the auxiliaries of any one driven by one system. The trouble, at present, is that the different methods of driving the auxiliaries are mixed on each ship, so that it is impossible to make an accurate comparison from the results obtained in daily working, on account of the great difficulty of determining the economic performance of each auxiliary separately.

Meanwhile, it should be noted that in all the latest United States naval designs, feed heaters are fitted, through which the auxiliaries can exhaust, thus causing a decided increase of economy; and provision is also made for exhausting (while the main engines are in operation) into one of the receivers. This last practice has prevailed for some time in American ships, and is attended by a considerable saving of coal.

The Steam Turbine

The remarkable performance of the *Turbinia* in 1897 attracted great attention to the possibilities of the substitution of the steam turbine for the ordinary type of engine. There can be no doubt of the remarkable speed made by the *Turbinia*, to which attention has already been called; but the question as to whether the result was due to the steam turbine, is by no means settled. A paper read by the Hon. C. A. Parsons, the inventor of the steam turbine, has been published generally in the technical press, and from an examination of the data given by him, it would appear that the really phenomenal part of the machinery of that vessel is the boiler rather than the turbine.

According to his figures, 1576 horse-power, requiring 25,000 pounds of steam, were obtained from a boiler with only 1100 square feet of heating surface, which gives 0.7 square foot of heating surface per horse power, and 22.7 pounds of steam per square foot of heating surface. These are absolutely unique results in boiler practice. Nothing was said about the air pressure carried, but it must have been very high. It is also to be noticed that the amount of cooling surface, 4200 square feet, was as abnormally large in proportion to the horse-power as the heating surface was abnormally small. The rotational speed,—2100 revolutions per minute,—was very much higher than anything ever attempted with an engine of the horse power which would have been necessary to drive the boat, and this, of course, tended to a reduction of weight, but the larger condenser would act the other way; and if an analysis is made of the portions of an ordinary engine which would be replaced by the turbine, it will be seen that the reduction of weight due to the use of the turbine alone is not necessarily very great. The truth is, so little is known about

TABLE III.—SHOWING INCREASE IN STEAM PRESSURES AND PISTON SPEEDS AND REDUCTION OF WEIGHT OF MACHINERY PER I. H. P.

NAME OF SHIP.	Date.	Type of Engine.	No. of Cyls.	Diameter of Cylinders. Inches.	Stroke. Inches.	Revs. per Min.	Piston Speed. Net.	I. H. P.	Air Pressure, Inches of Water.	Boiler Pressure, lbs	Kind of Boiler.
Warrior	1861	Simple horizontal trunk jet condensing.	2	112	48	54 25	434	5,469	0	22	Box.
Wampanoag	1865	Simple, geared surface condensing.	2	100	48	31 crank. 63 screw.	248	4,049	0	32	Box ; vertical water tube.
Devastation	1872	Simple, horizontal-trunk surface condensing.	4	80	39	76.92	500	6,652	0	30	Box.
Trenton	1876	3 Cylinder compound horizontal.	3	1 of 58.5 2 of 78	48	53.77	430 2	2,414	0	70	Cylinder S. E.
Inflexible	1878	3 Cylinder compound vertical.	6	2 of 70 4 of 90	48	73.26	586	8,483	0	61	Oval S. E. & D. E.
San Francisco	1888	Triple expansion horizontal.	6	2 of 42 2 of 60 2 of 94	36	125	750	9,717	2	135	Cylindrical D. E.
Minneapolis	1891	3 Screws ; triple expansion, vertical.	9	3 of 42 3 of 59 3 of 92	42	133	931	20,862	0.7	165	Cylindrical D. E.
Oregon	1892	Triple expansion vertical.	6	2 of 34.5 2 of 48 2 of 75	42	128.2	897.4	11,111	1	156	Cylindrical D. E.
Prince George	1896	"	6	2 of 40 2 of 59 2 of 88	51	101.8	865	12,280	1¼	155	Cylindrical S. E.
Terrible	1897	"	8	2 of 45 2 of 70 4 of 76	48	112.0	896	25,648	0	260	Belleville water tube.
Cushing	1889	Quadruple expansion vertical.	10	1 of 11.25 1 of 16 3 of 22.5	15	370	925	1,760	2.5	250	Thornycroft water tube.
Ferret	1894	Triple expansion vertical.	6	2 of 19 2 of 29 2 of 43	18	360.08	1080.2	4,474	4.1	175	Normand.
James	1895	"	6	2 of 18 2 of 27.5 2 of 42	18	367.1	1101.3	3,789	2.5	210	Reed.
Desperate	1896	"	8	2 of 20 2 of 29 4 of 30	18	397.6	1193.8	5,796	3.5	215	Thornycroft.
Quail	1897	"	6	2 of 21 2 of 32.5 2 of 48	18	367.2	1101.6	6,057	4.8	220	Normand.
Diadem	1898	"	8	2 of 34 2 of 55.5 4 of 64	48	119.1	952.8	17,262	0	291	Belleville water tube.
Foote	1897	"	6	2 of 12 2 of 19.25 2 of 22	16	395 7	1055.2	2,400	3.7	240	Mosher water tube.
Farragut	1898	"	6	2 of 17.25 2 of 24.75 2 of 37	21	340	1190	5,600	3	2,0	Thornycroft water tube.

U. S. Destroyers	1898	"	8	2 of 20.5 2 of 32 4 of 38	22	327	1199	8,000	3	300	Water tube.
U. S. Torpedo Boats	1898	"	8	2 of 14 2 of 22 4 of 25.25	18	350	1050	3,000	3	250	Water tube.
Cressy class	1898	"	8	2 of 36 2 of 59 4 of 68	48	120	960	21,000	0	300	Belleville water tube.
Turbinia	1897	Steam Turbine, 3 shafts, 9 propellers.	----	------	--	2100	----	1,576	--	200	Water tube.

Name of Ship.	Date.	All Machinery	Weights.	(In Tons)	Water in Boilers.	I. H. P. Per Ton of				Remarks.
		And Water.	Main and Auxiliary Engines Only.	Boilers and Water.		All Machinery.	Engines Only.	Boilers and Water.	Water in Boilers.	
Warrior	1861	898.2	421.6	476.6	171.7	6.09	12.97	11.47	31.87	Coal per I. H. P., 3.75 to 5 lbs.
Wampanoag	1865	1250	612.0	638.0	157.7	3 24	6.62	6.35	25.61	Coal per I. H. P., 3.15 lbs.
Devastation	1872	971.95	484.2	487.7	125.8	6.84	13.73	13.64	52.87	Coal per I. H. P., 3 1. to 4.42 lbs.
Trenton	1876	976	497.0	479.0	121.5	2.47	4.86	5.04	19.87	Coal per I. H. P., 2 32 lbs.
Inflexible	1878	1366.4	654.2	712.2	187.4	6.21	12.96	11.9	45.27	Coal per I. H. P., 2.38 to 2.74 lbs.
San Francisco	1888	914	433	481.0	125.5	10.63	22.44	20.2	77.43	Coal per J H. P., 2.4 lbs.
Minneapolis	1891	1920	694	1226	331.7	10.87	30.06	17.02	62.90	Coal per I. H. P., 2.3 lbs.
Oregon	1892	1068.4	436.4	632.0	143.2	10.38	25.46	17.58	77.58	Coal per I. H. P., 2.14 lbs.
Prince George	1896	1326.6	623.8	702.7	165.2	9.26	19.7	17.33	74.33	Coal per I. H. P. at half-power, 1.82 lbs.
Terrible	1897	2224.8	1076 4	1148.3	48.75	11.53	23.8	22.3	520.1	Coal per I. H. P. at three-quarter power, 1.71.
Cushing	1889	54.5	24.5	30.0	3.5	32.29	71.82	58.67	502.9	Coal per I. H. P., 2 lbs.
Ferret	1894	123 6	59.4	64.1	11.48	36.3	75.2	69.7	389.7	Coal per I. H. P. at 11 knots, 2.3 lbs.
James	1895	120.0	49.0	70.7	7.95	31.58	77.3	53.6	477.0	Coal per I. H. P. at 13 knots, 2.5 lbs.
Desperate	1896	127.95	61.5	66.46	7.75	45.3	94.3	87.2	747.0	Coal per I. H. P. at full speed, 2.5 lbs.; at low speed, 1.67 lbs.
Quail	1897	144.3	68.6	75.7	11.25	41 97	88.4	80.1	539.0	Coal per I. H. P. at full speed, 2.64 lbs., at low speed, 1.64 lbs.
Diadem	1898	1436.75	688.35	748.40	39.0	12.01	25.08	23.07	442.6	Coal per I. H. P. per three-quarter power, 1.59.
Foote	1897	50.82	24.5	26.32	4.0	47.22	97.96	91.19	600.0	Coal not measured.
Farragut	1898	120	56.8	63.2	10.5	46.67	98.58	88.58	533.4	From designs.
U. S. Destroyers	1898	189.1	89.8	99.3	15.9	42.30	89.08	80.56	503.1	"
U. S. Torpedo Boats	1898	79.75	35.5	43.75	6.6	37.62	84.5	68.58	454.5	"
Cressy class	1898	1800	858.0	942	49.3	11 67	24.47	22.29	425.9	"
Turbinia	1897	22	----	----	----	72.1	----	----	----	The I. H. P. is calculated from the thrust H. P. found from model experiments. See Journal A. S. N. E., vol. ix., p. 380.

NOTE.—This table is an extension of the one in Sir John Durston's paper read in 1897 before the International Congress of Naval Architects and Marine Engineers, the data he gave there being rearranged. The additions are for American ships and recent British ships.

the subject that we must, for the present, remain in an attitude of expectation. Meanwhile, the performance of the 35-knot boats which Mr. Parsons is building will be awaited with great interest, and probably fuller data will be obtainable after they have been tried.

Liquid Fuel

Ever since the discovery of petroleum in Pennsylvania in 1859, experiments have been made for utilising some of its products as fuel, and these have been so far successful that there are now numerous forms of burners which are efficient and reliable, both for crude petroleum and for the reduced oil. The conditions on board ship require that the oil shall have a high flash-point, so that there shall be no danger from volatile gases, and this restricts the possible fuel to petroleum refuse, called astatki in Russia, and to "reduced oil," or fuel oil, in the United States, which is practically the same thing.

The advantages of liquid fuel are well known, and have been repeatedly stated, the best presentation of the subject being Colonel Soliani's article before the Engineering Congress at Chicago in 1893. From the Italian experiments there described, one very important fact is deducible which is worth noting, as it corrects a very common, but mistaken, notion, namely, that the use of steam for atomising the oil is inadmissible on account of the large amount that would be required. In these experiments, it was found repeatedly that the steam used for atomising was less than 2 per cent. of the amount vaporised.

Inasmuch as the evaporative power of fuel oil is from 1.5 to 1.7 times that of coal, a simple calculation will show that, in one of our first-class torpedo-boats, if enough space be reserved for fresh water to make up for the steam used in atomising, the amount of fuel oil that can be carried in the present bunker capacity will more than equal the evaporative effect of the total amount of coal now carried. This is important because the steam atomisers involve very little complication, while the use of compressed air involves a good deal.

Another point in connection with the use of fuel oil which should be carefully noticed is that many people conclude, because the fuel oil has a greater calorific value than coal, that a boiler worked with liquid fuel will necessarily have a greater power than one worked with coal. This inference is not only not justifiable, but is probably erroneous. The experiments thus far made with liquid fuel under high forcing have shown a rate of combustion equivalent to only about 55 pounds of coal per square foot of grate, while there are reliable data of coal having been burned at the rate of more than 80 pounds per square foot of grate. There are practical difficulties in the way of providing an adequate supply of air for burning the fuel oil in large quantities under a given boiler that make it seem probable that, where the very highest results must be obtained, coal will be used.

The cost and difficulty of obtaining fuel oil in all parts of the world have thus far prevented its general use, and, as far as can be seen now, seem likely to continue to have that effect. On the United States coast, representatives of the great oil companies give the assurance that fuel oil can be supplied in large quantities for less than 3 cents per gallon.

The United States Navy Department intends, on the recommendation of the Bureau of Steam Engineering, to fit one of the torpedo-boats with oil fuel apparatus, and, if the bureau's anticipations of complete success are realised, all American torpedo vessels intended for operating on the American coast will probably be fitted for burning liquid fuel.

The Propeller

Progress in the design of propellers has been very great during the last forty years, and, indeed, during the last twenty. The early rules for design were as crude as could be, and remained so for a long time, in spite of Isherwood's famous Mare Island experiments and the investigations of Cotterill,

Froude, Griffiths and others. Originally the diameter was made as great as possible consistent with immersion, and the pitch and surface were empirical multiples of this dimension. Happily, such crude ideas are now entirely abandoned, and, after passing through an era of trial of all sorts of curious shapes, we have now reached a period where the principles governing correct design are well understood.

In the beginning the fundamental mistake was made of treating the screw propeller as analagous to an actual screw working in a solid nut, and this led to the error of believing that a very small slip was essential to efficient working. In fact, the propeller is a pump for driving water astern, and it is the reaction of this water that gives the propelling effect. Isherwood's Mare Island experiments showed conclusively, as we also know theoretically, that a small slip may be a sign of inefficiency and that a large slip is not inconsistent with a high efficiency.

The form of blade now commonly adopted is undoubtedly the best, and we know from experiment what proportions of pitch, diameter and surface to adopt to get maximum results. Having abandoned the idea that a large slip is an indication of inefficiency, the propeller becomes an elastic element of design, so that, although the turning of the propeller is the *raison d'être* of all the machinery, we can, within reasonable limits, design the rest of the machinery to suit other circumstances, assured that we can design a propeller to suit the engine which will be efficient.

The advent of the strong bronzes, and attention to such details as tailpieces and spherical hubs, have increased the efficiency of the screw by reducing frictional losses.

At intervals during the period attempts have been made to revive jet propulsion, but Thornycroft's elaborate experiment on a large scale in 1883, when a jet-propelled boat was compared with similar boats driven by a propeller, showed that it took twice as much power for the same speed with the jet. This has probably ended the subject with intelligent designers, except for such special cases as the life-boat described in a paper by Mr. John Platt before the annual meeting of the Society of Naval Engineers in 1898.

As far as the propeller itself is concerned, it seems to be now about as nearly perfect as it can be made; or, at least, the possible direction of improvement is not apparent.

With respect to the number of screws to give the best results, there is not an agreement. The performances of the United States cruisers *Columbia* and *Minneapolis* showed an economy by the use of three screws as compared with two, but it is claimed that tank experiments in Great Britain do not support this view. Apart from economy of propulsion, there are a number of reasons for using three screws in vessels of large power, and this is now the general practice in the French and German navies. The last annual report of the United States Bureau of Steam Engineering called attention to the tactical advantages of three screws, as shown very thoroughly in the naval battle at Santiago during the recent Spanish-American war.

Conclusion

In the survey which has been made, the possible lines of improvement have been suggested, and it is evident that, except in the substitution of water-tube for shell boilers, the changes are likely to be almost entirely in the perfection of details. There seems no probability of any such radical changes as have occurred in a number of particulars during the last forty years. The fact that the steam turbine has been a highly efficient machine for a number of years, and yet has not had any effect in displacing the steam-engine on shore (where it is free from some of the disadvantages which inhere in its use for marine purposes) would indicate that it is not likely to displace it on shipboard.

In spite of their greater thermal efficiency, the objections on the score of immense weight per unit of power and general lack of adaptation to marine service, will probably prevent the ex-

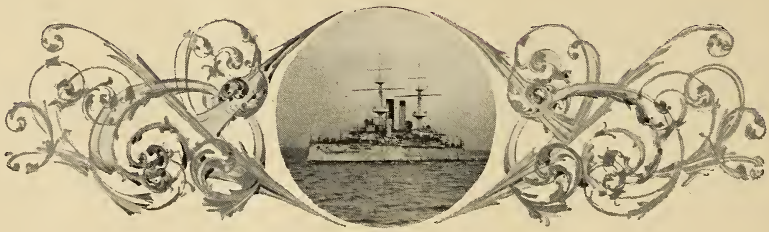
tensive use of any form of gas or oil engines unless changes of the most radical kind in their construction are discovered.

Nor must the idea be allowed to obtain that the steam-engine is such an extremely wasteful machine. The common method of stating the efficiency of the engine as the percentage of the total energy of the fuel which is turned into work is misleading and unfair. If the same method were applied in hydraulics, the efficiency of a turbine, working on a moderate fall at a high altitude, would be very low. When the efficiency is considered as the percentage of the performance of a perfect heat engine working with the same range of temperature, it is found to be a very respectable figure,—in the neighbourhood of 50 per cent.

The enormous gain in economy, represented by a reduction of coal expenditure per I. H. P. from five pounds to about one pound,—about 80 per cent.,—cannot, of course, be repeated, and it is very doubtful if we can ever reduce the coal expenditure to one-half pound per I. H. P. Still, there will certainly be some improvement.

Materials are being improved all the time, so that we may look for a further reduction of weight per unit of power.

We have, then, every reason for feeling pride in the past achievements of engineers in bringing the marine engine to its present efficient condition, and we may be confident that the coming engineers, who will be so much better trained and equipped than were those of the writer's generation, will do their part to continue the march of improvement.



THE VENTURI WATER METER

By Clemens Herschel

A VENTURI METER HOUSE ON A CITY SUPPLY LINE

THERE are water-meters, and water-meters; or rather, water-meters, and a water-meter. The first-named are the little cast-iron protuberances which the investigating householder is apt to find set in line of his service pipe now-a-days when he is supplied by a well-managed system of water works. Into the interior of these protuberances we will not at present attempt to pry. There are wheels and things inside, which perform marvelously perfect service in the case of the best of these so-called house-meters. Their more rapid introduction into universal use is greatly hindered at the present time by the multiplicity of designs on the market. Were the best meters, now offered for sale, publicly exposed as the best by a public competitive trial, as the best make of American turbines was thus exposed some years ago, it would not only remove from the market a great many of the patterns now made, thus increasing the sale of the others, but it would, no doubt, also cause many more water-meters to be used, thus increasing these sales possibly eight or ten-fold.

This is something which the near future will probably see accomplished, to the very great advantage of all consumers of water in cities and towns ; to their advantage in reducing the cost of the water consumed, and also to their advantage in enabling the water consumed to be taken from purer sources, or to be made better water.

But with all this,—and a book might readily be written upon the subject, as books have been written,—this article will not concern itself. These are the water-meters spoken of at the outset. As these become larger, they rapidly assume most astounding proportions as to size and cost, so that a meter of this sort to fit a 6-inch pipe is a ponderous affair, and very few have ever been made to fit a pipe so large as 12 inches in diameter.

For pipes larger than that, and, indeed, already a chieftain in the debatable ground between the 6-inch and the 12-inch pipes, there is only one water-meter. It is capable of metering accurately and economically the flow in any size of pipe, up to the total water supply of any city or combination of cities. It has metered the quantity flowing in a pipe 108 inches (9 feet) in diameter, amounting to 150 million gallons in 24 hours, and could as readily meter the full contents of the Niagara tail-race, or any other similar tunnel. At the same time, the meter, in the form of a specimen fitted to a pipe as large as a man's wrist, is a favourite practical illustration and working apparatus for lectures on hydraulics in most of the engineering schools of the United States

FIG. I.—A VENTURI METER IN A STREET MAIN

and Canada; so that the opening sentence may be said to have been justified,—there are water-meters, a host of them, for domestic and small factory use; and there is a water-meter, for street mains, penstocks, conduits, and tunnels. This last-named forms the subject of this article, and the history of its invention may not be without interest to the readers of these pages.

Venturi was an Italian professor of hydraulics and other physical sciences who lived about 100 years ago. During the French Revolution he was in Paris, and wrote some of his books in French. Others he wrote in Italian. All his writings show clearly the independent thinker and investigator. He is most noted for his experiments, made in Modena, about 1791, on the discharge of water through diverging ajutages, in which field he was a pioneer. So important were these experiments considered by his contemporaries that Venturi's account of them was translated into several languages at the time, among others into English, as in Nicholson's "Journal of Natural Philosophy," Vol. III., London, 1802.

Venturi himself does not suggest any use to be made of diverging ajutages, although he suggests several uses to be made of the "principle of the lateral communication of movement in fluids," which, to his mind, was the underlying principle in the action of such ajutages. As we shall see presently, inventions are as likely to precede, as to follow, a correct understanding of the principles according to which they operate.

Since the day of Venturi, his ajutages have been used for a variety of purposes, and their mode of action has become better understood. Among the first to make use of their properties was an American, Uriah A. Boyden, of Boston, the designer of the Boyden form of Fourneyron turbine, who died about 20 years ago.

This was a brother of the Boyden, also an inventor and a mechanic, in whose honour a grateful city has erected a bronze portrait statue on one of the commons in Newark, N. J., and which is believed to be the only example of such a monument having been erected to a mechanic by a city in the United States.

A full account of Boyden's invention,

called the Boyden diffuser, may be found in Francis's "Lowell Hydraulic Experiments" and in Weisbach's Mechanics.

Another such use made of these properties was a suction pump, exhibited in Hamburg, Germany, in 1869, and described in the "Zeitschrift des Ingenieur und Architekten Vereins in Hanover," 1873. They had also been made use of for anemometers,—instruments for measuring the velocity of currents of air. This brings us down to the year 1881.

In that year the inventor of the Venturi water-meter, who thus named the instrument in honour of the pioneer experimenter on the physical properties of diverging tubes, was the hydraulic engineer of a prominent New England water power company. It was his duty to determine and keep a record of the amount of water used daily and nightly by about eighty-five water-wheels and twenty-five or thirty manufacturing corporations. The turbines could be rated in a testing-flume, or otherwise, and thus be converted into water-meters; but to measure the amount of wash-water used by the mills,—quantities of material import in certain cases, —was a puzzle. There were the 20-inch and smaller pipes leading into, or through, the mill, that carried this water, and were painted black on the outside, and as cold and uncommunicative as their outside colour. Many a time he stood beside them and wondered if some practical, economical way could not be devised by which these

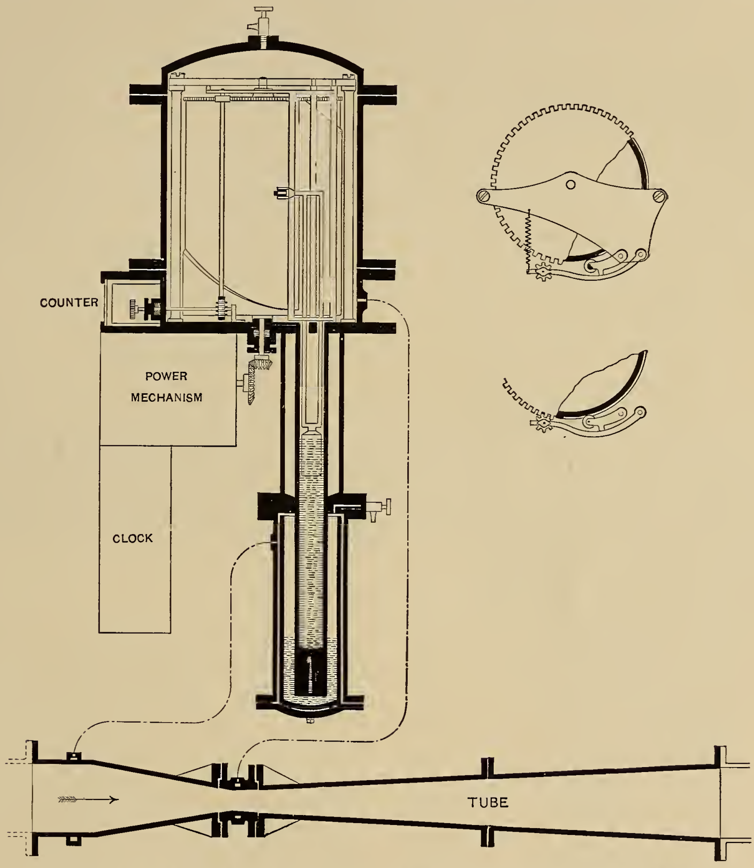


FIG. 2.—A SECTION OF A VENTURI TUBE AND RECORDING MECHANISM

pipes could be made to speak, and to indicate to the attentive observer what was passing within them. Gradually these strivings for the undiscovered took shape, and this is the shape they took.

We will put a short conical mouth-piece into the pipe at a certain point in its length, and this will dam up the water and will discharge it under the head thus artificially produced, thus increasing the velocity; then, to restore the velocity to its original degree, we will use the properties of the Venturi diverging tube, or of the Boyden diffuser, by causing the water to pass through a long, diverging cone back again to its original cross-section,—all this superimposed on the hydraulic conditions as they existed in the pipe at the outset. Then the artificially produced head above spoken of, acting on the short conical mouth-piece above referred to, will give us the measure of the quantity of water passing, while the rest of the apparatus will take care that no serious loss of head result.

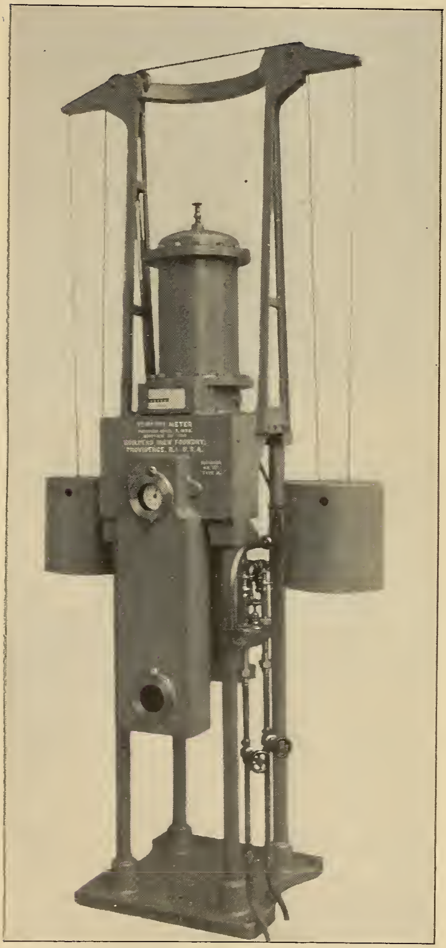


FIG. 3.—ONE OF THE REGISTERS USED WITH THE VENTURI METER

The opportunity to test this figment of the brain came five years later, in 1886, and the results of this test are described in the Transactions of the American Society of Civil Engineers, November, 1887, which give an account of two series of experiments on such meters, —then named the Venturi water-meter, —the one 12 inches, the other 108 inches in diameter at the two outer ends, and 4 inches and 36 inches in diameter at the throat or junction of the two cones, respectively.

These experiments at once led to a more refined interpretation of the forces, and discernment of the principles, governing the action of the apparatus, and many other experiments have since been made with Venturi meter tubes.

In 1890 the first three Venturi meters for actual use, two of 48 inches and one of 36 inches diameter, were set in the line of the main conduits of the East Jersey Water Company, then supplying the city of Newark, N. J., U. S. A. This system has since developed into water-works now supplying a number of municipalities in New Jersey, consuming from 55 to 70 million gallons daily. This large quantity of water is metered daily through two receiving meters, 48 inches in diameter, and again through eleven selling meters, from 48 to 12 inches in diameter. The records of the two receiving meters check up daily with the records of the eleven selling meters, or, if not, the management soon discovers where the leak is that causes the mischief. One large customer who receives only 27.5 million gallons daily, and has undertaken to make up his deficiencies by pumping, has dealt out to him 27.5 million gallons daily, with an error

FIG. 4.—REGISTER HOUSE AND DISCHARGE OUTFALL OF A 48-INCH VENTURI METER AT THE EAST LONDON WATER WORKS, ENGLAND

(corrected the next day) seldom exceeding 0.1 million gallons, the system followed being to run comparatively wild for 16 hours, or until 4 P. M., then see how much has been delivered, and cut off or increase the quantity so as to deliver the correct remainder during the next 8 hours.

One of the thirteen meters just named is arranged so that it will meter water flowing through the main pipe in either direction, which is a simple matter for the Venturi meter. It calls merely for a long cone on both sides of the throat, instead of on the down-stream side only.

It may not be out of place to state at once that a double-action meter of this kind was the very thing needed later, in the summer of 1898, to meet the requirements of legislation governing the eight water companies which supply the metropolitan district of London. These were ordered to connect their distribution systems, so that one district should not be in distress while a neighbouring district had enough and to spare. Palpably, a connection of that kind, once made, should allow for an interchange of supplies, and a double-acting meter as described was, in the summer of 1898, immediately set between two of these water supply districts. Others will unquestionably follow in London. With a moderate extra expense, the change of registration when the current reverses could take place automatically, either striking a balance on one register only, or else recording the amount that flows in each direction on one of two separate registers.

At the World's Columbian Exposition in 1893, in Chicago, a single 36-inch Venturi meter, now at the Worcester, Mass., Polytechnic Institute, measured all the water consumed on the Exposition grounds; and thereby hangs a tale. This water was furnished by the Hyde Park Water Works. They had set apart a certain pump to deliver water to the Exposition grounds; the

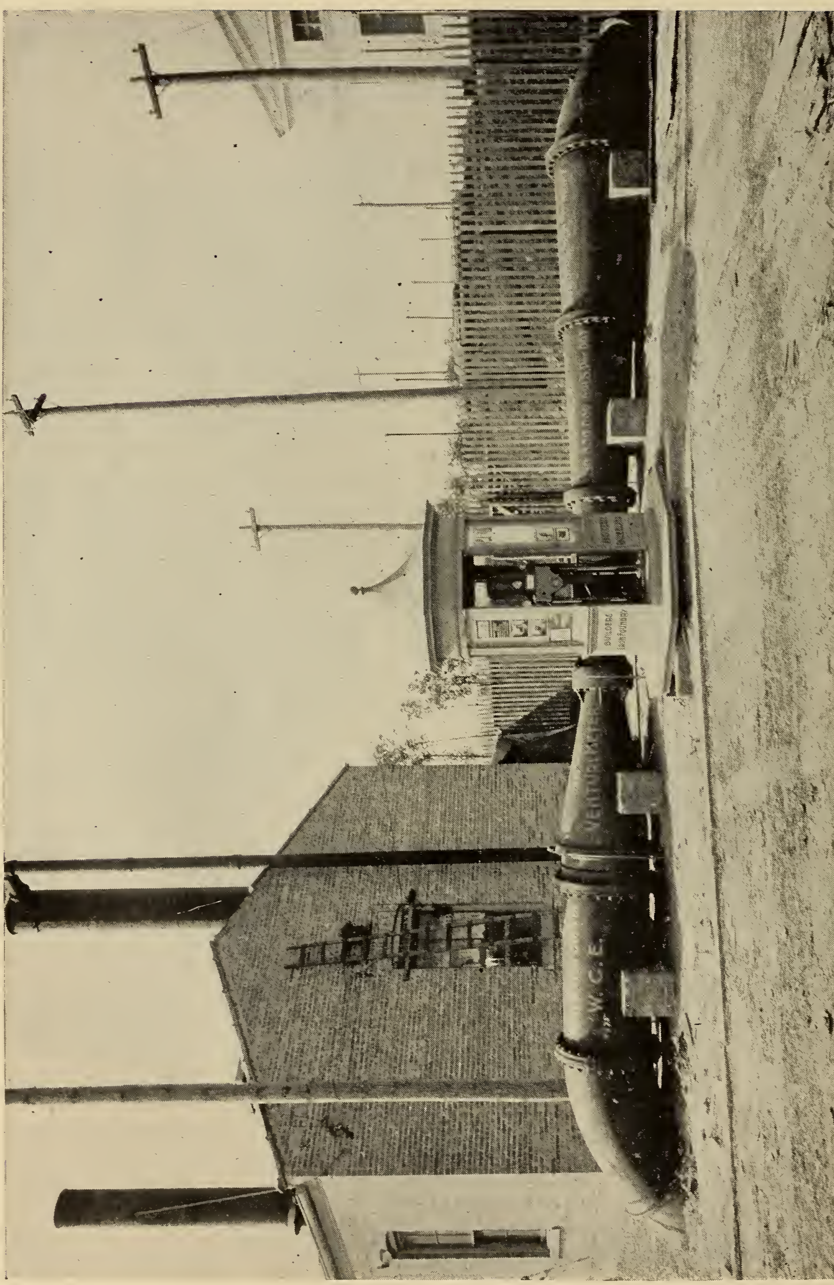


FIG. 5.—A 36-INCH METER AT THE WORLD'S COLUMBIAN EXPOSITION IN 1893

strokes of that pump indicated eleven million gallons delivered daily, and consequently, so reasoned Hyde Park, the Exposition authorities owed Hyde Park for eleven million gallons of water daily. Great, therefore, was the scorn of Hyde Park for this new-fangled notion of a meter when it indicated a delivery of only seven million gallons daily; greater still was this when an agent of the meter company had searched high and low, and had walked the whole length of the force-main from the Exposition grounds to the Hyde Park pumps, and yet could discover no reason for the discrepancy. Nothing was left of Hyde Park's scorn, however, when, on the return trip, this engineer stubbed his toe against an obstruction half buried in the sand and learned all about it.

"It is nothing," said they; "we have a branch from here to one of our districts, but it has been shut off. This is the gate-box."

"Get a wrench," quoth the agent; "let us see if it be shut off!"

And upon applying the wrench, the gate was found wide open. The trite and simple explanation of this seeming theft of water was, that the gate had been properly closed, but not sealed; and one of the old kind of trusted employees, finding it closed, concluded that it must have been closed by accident, or wrongfully, and proceeded to rectify the adjudicated error, in his own proper fashion. But it is plain that without the Venturi meter to discover the facts, the World's Columbian Exposition accounts would have shown in the end an appreciably less favourable balance sheet than they did.

In 1898 this meter was awarded the Elliott-Cresson Gold Medal of the Franklin Institute, of the State of Pennsylvania,—an award made from time to time as that institute deems an invention worthy of this, the highest, prize within its gift.

The report of the committee awarding this gold medal showed that the Venturi meter had been tested on five different occasions by the Bureau of Water, of Philadelphia, two 48-inch, one 20-inch, one 12-inch, and one 6-inch meter having been tried. It was also tested by the water departments of the cities of Brooklyn, and of Lawrence, Mass., and by the Solvay Process Company, of Syracuse, N. Y.

In the case of this company, strong brine, under 40 pounds pressure, was successfully metered by the Venturi meter, after several makes of meter had succumbed to the difficulties of the task. The Venturi meter has also been successful in the works of the Solvay Process Company, and elsewhere, in metering hot boiler feed-water. At this date there are about one hundred of these meters operating in the United States, and about fifty in the rest of the world, extending from the United States via England, Brussels, Vienna, Moscow, Meerut (East India), Rosario (Argentine Republic), and St. Lucia (West Indies) around the globe back home again.

Fashion may be supposed to have little influence on mechanisms; but a close study of the demands of different countries and of one and the same country at different times, soon shows this idea to be erroneous. Thus the moment the Venturi meter made its appearance in Great Britain, it was confronted by the demand of British engineers for a continuous record, or paper diagram, showing the operation of the meter. This could be, and was, easily met. Indeed, the construction and action of the whole apparatus is such that the same meter can readily, and has repeatedly been made to, register both ways simultaneously,—on dials, as an ordinary gas, or house water-meter, and on a paper diagram, like other recording instruments.

It is now in place to speak of the registering mechanisms that have, to date, accompanied the Venturi meter tube. The tube alone, set in the line of a water main, and fitted with two of any form of piezometer, or with two pressure gauges, will enable an engineer to observe and to read, by inspection of a table, the quantity of water passing the meter at any moment.

But to read the quantity that passes the meter during any appreciable inter-

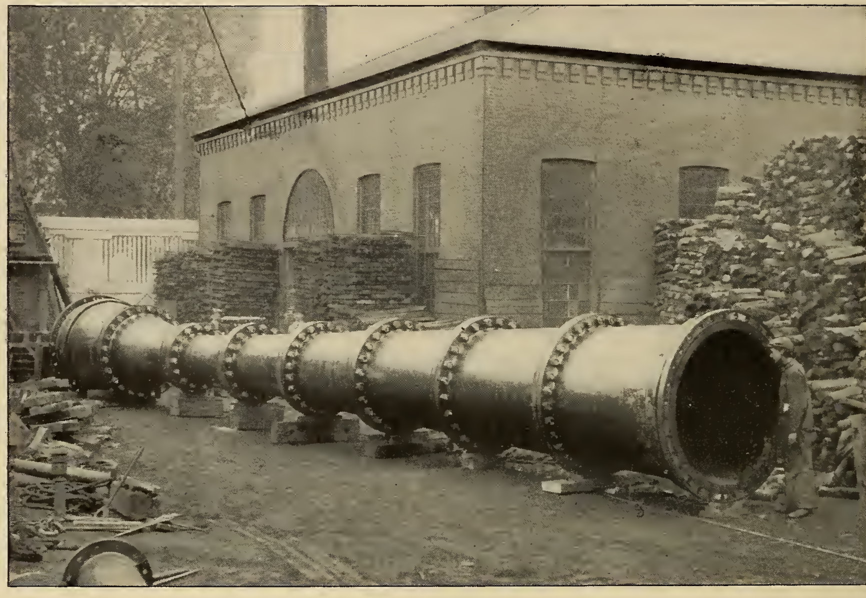


FIG. 6.—A 60-INCH VENTURI METER

val of time, some form of integrating mechanism is necessary. Many such have already been devised, by far the most successful of which received the John Scott Legacy Premium and Medal from the City of Philadelphia, on the recommendation of the Franklin Institute, in 1898. Its inventors are Frederick N. Connet and Walter W. Jackson, employees of the Builders' Iron Foundry, of Providence, R. I. This is a drum integrator, operated by clockwork, wound once a week or oftener, and recording, as ordinarily made, once every ten minutes, the records being automatically summed up and the sum recorded on ordinary dials.

Inasmuch as this register is operated by the difference of pressure in the two pipes that connect it with the meter tube, and inasmuch as there is no flow of water in these pipes, it causes no disarrangement of the whole apparatus to attach other instruments of record or of observation to the same two pressure pipes. This is what the British makers have done, thus producing a register that records both on dials and on a moving sheet of diagram paper.

The ½-inch or larger pressure pipes referred to are successfully made of lead-lined iron pipe, embodying strength and freedom from rust by the stagnant water within them, and have been made as much as 500 feet long, at times, to connect the meter tube with the register placed in some convenient cellar, or other frost-proof receptacle.

But two criticisms have ever been made upon the Venturi meter; the one (1) relating to the range in quantity that it is capable of measuring; and the other (2) relating to its supposed liability to change of rating by rust within the meter tube.

1.—The range of the meter depends somewhat on the permissible loss of head in passing the meter. If this is to be kept below two feet of water head as a maximum, the range of quantity will be from about 1 to 13 or 14, and extending up to from 1 to 20, for a greater permissible total loss of head in passing the meter.

When not in action, no loss of head need obtain, the pressure around the meter being equalised by a bye-pass. Ordinarily no bye-pass is needed. None, except in small street-mains, occasionally over-strained in fire service, has ever yet been set.

But to give the meter a greater range,

the familiar device of "a small hole for the kitten and a large hole for the cat" has been used. That is to say, two meters, a large one and a small one, are set up side by side. When small quantities are passing, the little one alone is in operation. When large quantities are needed, a weighted check-valve opens automatically by the increased head on the apparatus and sets the large meter in operation. This, again, was a requirement made in Great Britain. In the United States there are few mains in which the quantity to be metered varies more than from 1 to 13 or 14 or 20, so that a single meter will always suffice.

2.—The simplest way to prevent rust inside the meter-tube would be to line the whole of it with brass. The throat of the meter-tube has always been thus lined. Some meters, now in service, present upon their interior a wooden surface, being built up of wooden staves inside a cylindrical riveted steel pipe. The meter-tube has a length of only about ten times the diameter of the main pipe to which it is connected at either end. The distance from the up-stream end to the throat is only about one-quarter of that. And an increase of absolute head, measured on the last-named short length, must contain but a very small increase of difference of pressure actually measured on that short length, the rest being caused by the true hydraulic action of the Venturi tube. This is true for a cast-iron unlined tube. For a wooden-lined tube it would be less still, and for a brass-lined meter-tube it would disappear entirely.

Many hitherto impossible operations in the administration of water supply works have been easily accomplished by the Venturi meter; but it is capable of doing much more such work never yet done. For instance, though invented for the express purpose of metering wash-water as used in paper and other mills, it has not yet been used for that express purpose. Similarly, it is readily arranged to meter the quantity of water used for generating power, and can be set up for that purpose either in the head-race or in the tail-race of power plants. Two 54-inch meters of that kind are now in use by the Pioneer Electric Power Company of Odgen, Utah. Sewage may also readily be metered in this way. The meter-tube could be lined with glazed or other brick, and only the throat made of metal.

For irrigation practice, cheap meters with cheap registers could allow each

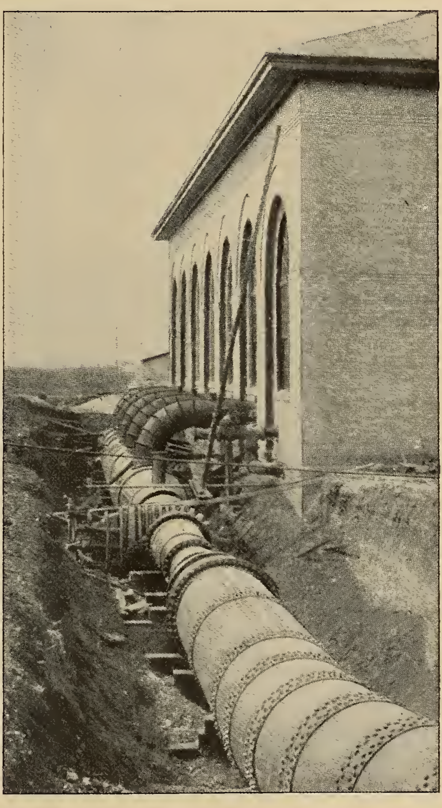


FIG. 7.—A VENTURI METER AT THE POWER STATION OF THE PIONEER ELECTRIC POWER CO., AT OGDEN, UTAH

farmer to draw water when he wanted it, and pay by measure for the quantity drawn, instead of selling by the archaic method of delivering the water at fixed times or "by turns," as now done, and compelling payment whether used or not.

It was stated above how British engineers had insisted upon having their meter registers fitted with a drum and

clock-work for taking continuous records. This converts the Venturi meter into what is called a "waste-water meter." It has the great advantage over the forms of waste-water meters hitherto used of being unlimited in size, so that it can be inserted into a street main of any diameter, as against the limitation hitherto, to pipes of 6, 8, or 10 inches diameter.

Moreover, it presents a free channel to the water. Fish, sticks of wood or other obstructions pass through freely. Again, one register would suffice for a whole city. The meter-tube would be set permanently in the line of the street mains and piped to the sidewalk, while the register would be moved about from one sidewalk connection to the others, as a record was wanted.

The disgraceful confession of water works superintendents that from 25 per cent. to 30 per cent. or more of the water received is wholly unaccounted for, need continue no longer than they choose to let that state of affairs continue, if they will look for leaks in street mains and elsewhere by means of Venturi meter-tubes, permanently set in the line of the principal main pipes.

Finally, the standard method for metering large quantities of water will, before long, be recognised as that by the Venturi meter. The weir needs but to be studied to be recognised as a most fitful, changeable, deceptive, clumsy instrument. Its range of coefficient, in all but the most expert of expert hands, is frightful to contemplate, when accuracy is desired. Only too many of the so-called tests of the Venturi meter by means of a weir, are, in truth, a test of the skill of the weir operator by means of the standard form of Venturi meter, which altereth not.

Where ordinary house meters are considered accurate when varying 7 per cent., and a badly handled weir may vary 10 per cent. or 15 per cent., such ranges of error are unknown in Venturi meter practice. Such meters are guaranteed accurate within 2 per cent. Specially rated, and brass-lined, there is nothing to prevent their being absolutely correct, so simple and so uniform is their action. The thirteen meters of the East Jersey Water Company, spoken of in this article, invariably agree in their records within a fraction of 1 per cent., accounted for partly by a balance of errors, partly by unavoidable leakage on 50 miles of conduit. The prospect to the Venturi meter for usefulness to mankind in manifold ways has never been so bright as now, after 10 years of its operation in public.

Suppose, in the meter-tube shown in Fig. 2, that the water were at rest! In that event, the pressure against the walls of the tube would be the same throughout its length.

Now, suppose the water to be in motion! This would immediately cause the pressure against the walls of the meter-tube to diminish, and this pressure would diminish to a greater extent at the throat than at the up-stream end.

This *difference* of pressure, of the water at the up-stream end and at the throat, constitutes an *exact* measure, as has been proven by repeated experiments, of the velocity through the throat. Then, having thus given the velocity through the throat, and the area of the throat, the quantity of water passing the meter-tube is readily arrived at.

The meter-tube is surrounded by a hollow pressure chamber at the points where the pressure of the contained water is to be measured. The pressure chamber is connected with the interior of the tube by four, six, or eight carefully constructed, brass-lined piezometer holes.

Fig. 3 shows the form of register which has been in use during the past seven years. It is shown in cross-section, connected with a meter-tube, in Fig. 2.

Fig. 4 shows the meter house of the East London Water Works, near London, containing a 48-inch Venturi meter, and the measuring weir formerly used at the same place.

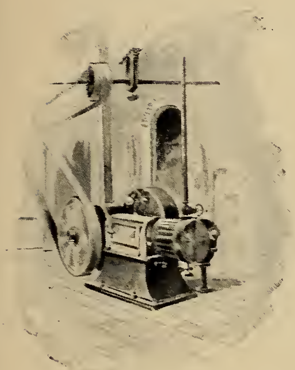
Fig. 6 shows a 60-inch Venturi meter set up in the yard of the Builders' Iron Foundry, of Providence, R. I., previous to shipment.

Fig. 5 shows the 36-inch Venturi

meter set above ground as an exhibit of the World's Columbian Exposition in Chicago, in 1893. This meter metered all the water supplied to the Exposition grounds. The little illustration at the beginning of this article shows one of the frost-proof meter houses built at Worcester, Mass. The whole water supply of that city is measured through four Venturi meters. In Fig. 7 finally is shown one of two 54-inch Venturi meters used at the hydraulic power station of the Pioneer Electric Company, at Ogden, Utah.

POINTS ON BOILER AND ENGINE SELECTION

By William O. Webber



IT seems like a hackneyed question,—"Which is the best boiler?" or "Which is the best engine?"—but it will always be one of particular interest to the man who pays for the power. There is, of course, no one best kind of boiler or engine for all conditions; indeed, the best kind of boiler and engine for one set of conditions might be the worst, all things considered, under some other set of conditions. It would be unwise, for example, in equipping, say, a small saw-mill in a new country, to use anything but the cheapest form of portable boiler and engine. But where it is desired to establish a permanent plant to furnish power twenty-four hours per day and for three hundred and sixty-five days in the year, like a water works pumping station, it is perfectly clear that the most expensive and perfect type of boiler and engine, which by reason of this increased cost will give an additional economy in foot-pounds of duty, is the one to be established, and the only difficulty in this latter case is in determining which is the best type of both boilers and engines for this set of conditions.

To look a little further into this last line referred to, the duty performed by large pumping engines has increased very rapidly in the last few years. One of the first pumping engines to give anything like high duty was the Leavitt pumping engine installed at Lawrence, Mass., in 1879, which gave a duty of 111,548,925 pounds, corresponding to a fuel consumption of about 1.8 pounds of coal per horse-power per hour. The indicated horse-power of this engine was 148, and the pounds of coal per indicated horse-power was 1.63 pounds. The pounds of steam used per indicated horse-power were 16.5.

Since that time pumping engines have been gradually improved, until a duty of 158,000,000 pounds is to-day an accomplished fact. This represents practically 1.25 pounds of coal per horse-power per hour. It will readily be seen that the value of the coal saved per annum between these two types of engines would equal the interest on an enormously large difference in first cost.

To come down, however, to the more average problem which confronts the general purchaser of steam boilers and engines, it is safe to say that where there is sufficient room and land is not too expensive, and where the results from an explosion would not be attended with large loss of life and property, there is probably no type of boiler which has given more universal satisfaction, will stand more general abuse, and can be more easily handled by the average fireman than the plain cylindrical, tubular boiler.

Some of the highest figures which the writer ever obtained in boiler tests were

obtained on this type of boilers, notably a 78-hour test which gave an efficiency of 78.28 per cent., a 60-hour test which gave an efficiency of 76.53 per cent., and another 60-hour test which gave the remarkably high efficiency of 82.32 per cent. The actual evaporation per pound of dry coal during these three tests was 10.28, 10 61 and 10.54, respectively, and the evaporation per pound combustible from and at 212° was 12.61, 12.31 and 13.15, respectively. The reason for these very high efficiencies was that the boilers were thoroughly set and carefully handled, and were developing from 35 to 40 per cent. below their normal rating. There are a great many points of advantage in this type of boiler, notably the readiness with which the tubes can be cleaned, the large steam liberating surface, the ease with which the water level can be maintained, and the fact that, having a brick furnace, the temperature of combustion can be maintained at a sufficiently high point, so that when properly set and properly fired, there is very little waste in the way of unconsumed carbon going up the stack.

Next to this type in point of selection, where ground space becomes more valuable, but where plenty of room can be had vertically, the writer would recommend a vertical boiler, but of a type which can be set upon a brick furnace, as he believes that the ordinary type of vertical boilers, with water-inclosed combustion chambers, and of limited height between the surface of the grate and the crown flue sheet, is uneconomical. Where, however, we come into a thickly settled community like a city, where every foot of land is valuable, and where the results of explosions might be attended with great loss of life, some of the water-tube boilers are preferable to the cylindrical boilers, although it is a much-mistaken idea that serious accidents cannot occur with boilers of this type.

As to the engine problem, the ordinary factory, situated in the country or suburban district, where the line shafting does not run over 250 revolutions per minute, and where there are ordinary good facilities for receiving and handling coal, would be best served by some form of slow-speed Corliss engine where the load is reasonably steady, or a single-valve automatic engine where the load is very variable. If a sufficient supply of water is readily available and the power to be used would exceed 150 horse-power, it is worth while to run this type of engine condensing. If the power to be used exceeds 200 horse-power it would pay to have a compound condensing engine. The writer believes that there is comparatively little economy in compounding engines unless they can be run condensing. When the situation of this plant is such that the cost of fuel becomes one of more importance, some form of four-valve, shaft governor, medium-speed type of engine should be selected.

In a small plant under similar conditions, where electric lighting is also to be considered, or the running of some class of machinery where extremely close regulation is an essential, the higher-speed, shaft governor, automatic engine becomes a necessity; but if the plant is a large one it will be even more economical to use the medium-speed engine for the main plant, and a separate high-speed automatic engine to drive the electric light plant. This is especially true if any of the machinery in the manufacturing part of the plant will throw heavy and sudden loads upon the main engine.

As we approach the cities, where land becomes more valuable and the sizes of these engines are large, the vertical type becomes preferable. Again, directly in the city we must consider only high-speed, shaft governor engines, for the reason that they will produce a maximum amount of power in a minimum amount of space. Where the distribution of this power is to be electrical and the units of electrical power can be as high as 75 kilowatts, direct-connected engines and generators are to be preferred, and this means again the high-speed engine. It is, however, a great mistake to believe that the best results can always be obtained from a high-

speed engine, and the writer believes that they should never be employed unless the use of some other type of engine is absolutely prohibited.

The best results from a high-speed engine are obtained in a close range of from $\frac{3}{4}$ to $1\frac{1}{4}$ times the rated power of the engine, and a better performance than 30 pounds steam per indicated horse-power per hour is rarely obtained. Where the proportion of the power to the rated capacity of such an engine becomes as low as $33\frac{1}{3}$ per cent., the steam consumption will closely approach 40 pounds per hour. The medium-speed, four-valve automatic engine will readily yield an economy of 25 to 26 pounds, from $\frac{3}{4}$ to $1\frac{1}{4}$ times the rated power, and should not go above 32 pounds at one-third of the rated capacity of the engine.

The simple Corliss condensing engine will show an economy of 23 pounds, and the compound condensing Corliss will show an economy as low as 16 to 18 pounds under the best conditions. All things considered, a mistake seems to have been made in the adoption of the high-speed, short-stroke engine for all classes of work, and there is a healthy reaction in favour of a medium-speed automatic engine, with separate steam and exhaust valves, preferably a four-valve engine with valves of the gridiron type, with extremely small clearance space, which, in nine cases out of ten, would give much better economical results than the high-speed engine.

Of course, it is impossible to lay down here a complete set of rules for the selection of engines. So many different elements enter into the consideration of such a selection that it would always pay an intending purchaser to consult an expert in this line of work as to the type of engines and boilers to be chosen. By so doing he could generally save more in the cost of fuel in the first three months than would pay the consultation fees.

There are a number of points which should always be considered, such as the conditions where the load is practically steady, conditions where the load would vary from 50 to 125 per cent. of the rated power of the engine, and other cases, like that of street railway plants, where there is an extreme variation from practically nothing to 150 per cent. of the rated power of the plant. Where the load is steady, a medium-speed compound engine would be found very efficient; where there is a great variation in load, this type of engine would very rapidly lose its economical efficiency, and the high-speed multiple-cylinder should be substituted for it.

Where steam is used for manufacturing purposes in large quantities throughout the year, the simple, less economical, less expensive type of engine should be selected, as the use of the steam the second time would more than make up for the lack of economy in the engine, and the type of engine which would require the least amount of attention and repairs should in all cases be decided upon.

It may not be amiss to refer, in conclusion, to the mistake which has been made in the last few years in believing that the steam engine had been so improved that, no matter of what size or of what type, a horse-power could be produced, on an average, for the sum of $23 per year. This, in the United States, is true only of engines above 1000 horse-power, of the slow-speed, compound, condensing type. The power with engines of 500 H. P. will cost at least $30 per year; of 250 H. P., $40; of 200 H. P., $45; of 150 H. P., $53; of 100 H. P., $65, and very few engines of 50 H. P. only will produce a horse-power at less than $100 per year.

Current Topics

Two of the most important engineering enterprises now under way are the building, in Africa, of the railway up the Nile to Khartoum, possibly of later extension to the African lakes still further south, where the Nile takes its rise, and the Uganda Railway in British East Africa, running from the Indian Ocean to Victoria Lake. These two lines, according to a recently published account, will, beyond a doubt, some time meet in mid-Africa and complete an all-British route south from the Mediterranean across the equator to the Indian Ocean, leaving connections with Buluwayo and the Cape for a later date. The Uganda Railway has its eastern terminus at Mombasa, a British base just north of Zanzibar. The place is about four degrees south of the equator, and work on the line was originally begun two or three years ago. The workmen have been struggling inland in a northwesterly direction ever since. The railhead is at present in a temperate climate, nearly 4000 feet above the sea and about 235 miles from Mombasa, the starting point. There has been an aggregate advance, so it has been stated, of about 96 miles in seven months.

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AMONG the difficulties attending the building of these lines, the labour problem seems to have had a prominent place. Suitable workers were not easily recruited, though native and Indian sources of supply of some value were found. Again, owing to the thickness of the brush, the severe lack of fresh water and the natural difficulties of the country, it was impossible to transport material ahead of the rails. Actual construction, therefore, was slow and costly. Some idea of the scarcity of good water may be formed when it is known that in the first 250 miles from Mombasa, the only pure supply met with is that of the Tsavo River at mile 135. All other sources are more or less impregnated with salts and lime, very injurious to the boilers of locomotives. It was as wet at some seasons as it was dry at others. In the spring of 1897 there was a rainfall of 40 inches in two months alone, and this caused great mortality among the coolies. The tsetse fly, as far as 240 miles from the coast, destroyed the greater part of the transport mules and many other animals working in that zone. Bullocks have been imported from India; but they, too, have died in large numbers. All kinds of wild animals infest this region, and lions are a real source of danger to man and beast. Four bullocks were killed during one month by lions, and in spite of strenuous efforts to despatch these animals, for the de-

struction of one of which a reward of 250 rupees was vainly offered, twenty-two men were carried off in the six months ending with September, 1898, some having been seized inside their tents and waggons. The first section of 100 miles of road was opened to the public for freight traffic in December, 1897, and for passengers on February 1, 1898. Freight until recently went through as far as Simba, 235 miles from the coast. The trade in ivory over the line is already considerable, and is expected to increase.

In considering the problem of heating the large department stores which are now to be found in nearly every big city, it is very well worth taking into account the animal heat distributed by the many customers who come into such establishments. That this is considerable is evidenced by the experience of at least one engineer, who, in one such case, found that after 9.30 A. M., on a day in mid-winter, with the thermometer at the freezing point, no other heat was needed to keep the place warm. This fact, however, emphasises as well the great need of a good system of ventilation in such buildings, as without it the air would soon become vitiated much beyond any reasonably permissible degree.

Apropos of all that has been printed within the past month or two concerning that late distinguished Philadelphia citizen Keely, the motor man, whose motor never "moted" just right, there comes to mind a once suggested possible connection between Keely's mysterious working force and the water supply of the city of Philadelphia, which, for many years, had the reputation of being almost the worst in the world. Keely, as is just now fresh in memory, promised to accomplish all sorts of wonderful performances through the possibilities stored up in nothing more than a cup of water, one of the prospective achievements having been the running of a fast express train from Philadelphia to New York in a half hour or thereabouts, with the aforesaid cupful of water as one of the mainsprings of the requisite power. Some one, therefore, said that, after all, there was nothing wonderful about it, providing the water used were Philadelphia water which had been left standing for a day or two. The animals in it would, by that time, have become large enough to climb out and help push the train.

What is probably the earliest example of the gimbal ring movement is shown in the little reproduction on this page from an illustration originally published in a work on machinery written by Vittoria Tonca, and printed at Padua about the middle of the seventeenth century. To use Tonca's own words, "the carriage is so designed that its bed or couch is always horizontal, and notwithstanding that its wheels,--owing to the difficulties and roughness of the road,—may move in a very irregular way, it has been so skilfully contrived that its occupant remains practically undisturbed. The first movable frame of this invention is provided with pivots, *A D*, which are supported by, and turn in, the sides of the main frame of the carriage. Within this first frame is an-

AN EARLY EXAMPLE OF THE GIMBAL RING MOVEMENT.

other frame, having pivots, E F, supported by, and turning in, the ends of the first-mentioned frame. It will be readily seen that, regardless of the relative position of the wheels, the trough-like bed of the carriage will always maintain a horizontal position." It would seem probable, indeed, therefore, that the now so familiar means for suspending the mariner's compass was anticipated by this early device.

CLAIRE FURNACE AT SHARPSVILLE, PA., FIVE SECONDS AFTER EXPLOSION

THE illustration on this page has been made, through the courtesy of Mr. F. B. Richards, of Cleveland, Ohio, from a photograph taken about five seconds after the explosion of Claire furnace, at Sharpsville, Pa., last year. Mr. Richards very aptly mentions the circumstance that the photographer happened to be, at that particular moment, in the proper position and in the necessary condition of preparation to take this picture immediately upon the unexpected occurrence, and to get an excellent view of the appearance it presented, as a coincidence not likely to occur often. Furnace managers are not able to foresee accidents of this kind so as to have artists on hand at the critical moment. In a note concerning the explosion which Mr. Richards presented at a recent meeting of the American Institute of Mining Engineers, the following data were given:—Claire furnace is 75 feet high by 16 feet bosh-diameter and 10 feet 6 inches hearth-diameter, and is working with 13 tuyeres on an ore-mixture containing 37.5 per cent. of a Mesabi ore, 25 per cent. of which will go through a 100 mesh sieve, the balance of the mixture being Menominee and Marquette range hematites. On September 10, 1898, there had been two explosions while working 50 per cent. of Mesabi ore in the mixture; hence it had been reduced to 37.5 per cent., as above stated. As early as 6 A. M. on September 15 the furnace commenced making light slips, which continued at intervals of about 30 minutes up to casting time, 10.30 A. M. After starting up again after the cast, the slipping continued, the stock settling so hard at times that one standing beside the columns could feel the jar. The red ore-dust showed continuously at the chimneys of the boilers and

stoves, indicating an irregular settling of the stock. The slipping had been so extreme that the coke and melted cinder had packed tight in the hearth, and no cinder could be got at flushing-time; it came back into the blow-pipes with succeeding slips, but was forced back again by the blast. There are on the furnace, directly under the platform, two explosion-doors 6 feet in diameter; but up to this time none of the slips had opened either of them. At 1.30 P. M. there was a terrific explosion, and both explosion-doors opened to their full capacity, hurling ore, coke, scrap and limestone for several hundred feet. A piece of limestone 6 inches in diameter was picked up 425 feet away from the furnace. The great cloud seen in the illustration was composed of ore-dust, gas and finely-divided carbon. The latter was in the form of lamp-black, and, as can be seen, was of considerable volume. No damage was done, except to the windows of the office and laboratory, and the roof of the blacksmith-shop. The hopper was fastened down; otherwise it would probably have been thrown out, as has happened in other cases of this kind. Operations were resumed at once; cinder was drawn in the course of the afternoon; and the furnace cast 33 tons of white iron at 6 P. M., and on the following cast made the usual quantity of good gray iron.

Gas and oil engine development has not been encouragingly rapid, except where relatively small powers are concerned, and the large engine, of 100 H. P. and more, has been slow, indeed, in convincing the power user that it is the kind of engine which may reasonably be expected to work satisfactorily, and, all things considered, economically. It is worth noting, therefore, that a plant of eight large gas engines, four of 260 H. P. and four of 210 H. P. each, has been reported as about to be installed at the Lot's Road pumping station of the London County Council, and will thus afford the latest evidence of the important work which engines of this class may be expected to successfully perform. The plant will probably be the largest one of the kind in existence.

BLOCK-SETTING TITAN CRANES

REFERRING to the article on "Block-Setting Titan Cranes," by Mr. Joseph Horner, which appeared in the January number of this magazine, the following letter was published in a recent issue of *Engineering:*—

Sir—Our attention has been called to an article on "Block-Setting Titan Cranes" in "Cassier's Magazine" for this month. We shall be glad if you will allow us to state that we are in no way responsible for the statements in the article, many of which are incorrect; and as all mention of our name has been omitted throughout, may we also state that we constructed the following machines, to which unacknowledged allusion is there made :—

1. The Titan, for Kurrachi, mentioned on page 173.
2. The East London Titan, page 173.
3. The machinery for the Tynemouth Mammoth, North Pier, page 175.
4. The machinery for the Tynemouth Mammoth, South Pier.
5. The "elaborate model," mentioned on page 185.
6. The 6-tons block-setter, page 177.
7. The "smallest block-setter ever made' (*sic*), for East London, page 177.
8. The similar machine for Port Alfred, page 177.
9. The large Peterhead Titan, mentioned on pages 177 and 180.
10. The Vera Cruz Titan, mentioned on page 177.

We are, sir, your obedient servants,
Pro Stothert & Pitt, Limited,
Walter Pitt
(Managing Director).
Bath, January 18, 1899.

To this the following reply was made

by Mr. Horner in a letter also addressed to the editor of *Engineering* :

SIR—I sincerely regret that the letter of Messrs. Stothert & Pitt, in your issue of 20th, compels me to ask the favour of the insertion of a reply. I should not, however, have offered any public explanation of what is a private affair but for the attempt made in that letter to throw discredit on the accuracy of my article in "Cassier's Magazine."

I take exception, first, to the opening of the letter. It would imply that Stothert & Pitt knew nothing of the article in question until their "attention" had "been called" to it. On the contrary, they were as well aware as myself that the article was in the press, and they had read the proofs through with me, so that to say that their attention had been "called" to it, sounds disingenuous, and would convey a wrong impression.

Regarding the question raised in that letter, of responsibility for the article, this would naturally be attributed to the writer who signed it, and to no one else. The manuscript had never been seen by any one, except myself, before it was sent to the editor of "Cassier's."

Messrs. Stothert & Pitt complain that "all mention of our name has been omitted throughout." Now, though I did not, of course, write the articles to advertise any firms, but to give the general reader a good idea of what has been done in Titan building, I regret as much as they themselves, the omission in question, and expressed that regret personally to them last December. I am, therefore, surprised that they have made this a matter for public complaint, particularly as the absence of illustration of their machines is due to *their* delay in supplying photographs. The following are the facts :—

I wrote the article without inserting fully the names of manufacturers, intending to add these in proof, in connection with illustrations when obtained. This I explained to Mr. Pitt last December. Mr. Pitt was asked for photographs last August, at the same time as other firms, who promptly responded. Mr. Pitt declined to supply them unless, and until, he could see proofs of the article. On receipt of these in December last, I went through them carefully, line by line, with Messrs. Stothert & Pitt, and inserted, at their desire, some details relating to their practice which is covered by the last two or three years, and which the article itself did not cover, and inserted, too, the name of the firm. The proofs were posted, and the photographs were supplied a few days later. But time had been lost, the printing of the article had to go on, and so neither photographs nor any corrections, or additions, appeared in print. Stothert & Pitt are not alone in the absence of their names from the letter-press. Jesson & Appleby, Ransomes & Rapier, the John Cockerill Company are not mentioned by name. But the photographs which they supplied on request last August and September tell their story.

In reference to the "statements in the article, many of which are incorrect," this is too vague. It implies that the article was incorrect before Stothert & Pitt's suggestions were embodied, but correct afterwards. Now, these included variations in practice, and the insertion of names chiefly, and their absence does not detract from the value of the article as an account of the development of the Titan crane. The editor of "Cassier's" had the proofs, with the additions made, and these, therefore, are available for reference, if required. I think if the editor had deemed these additions of sufficient importance to justify the postponement of the printing of the article, he would have done so.

I note in Stothert & Pitt's letter one statement called in question :—The "smallest block-setter ever made" (*sic*) for East London, page 177. This is a false quotation. In my article the reading is :—"Among the smallest block-setters ever made, etc.," followed immediately by :—"Among the largest are the machines, etc.," which is quite a different construction. Stothert & Pitt have made smaller machines than these, as small as six and three tons. But a 3-ton long radius crane can hardly be dignified by the name "Titan," any more than a Temperley transporter or a Brown coaling crane. To overload a semi-popular article with minutiæ of this kind, and repetitions of the names of firms, would ruin it in the opinion of an editor who gauges the requirements of his readers.

In conclusion, I have given, I believe, the only magazine account of the development of the block-setting Titan, as made by several firms—British and Continental. It is as full of information as the limits of an article will permit. I have also written of what I know well. The attempt made to throw discredit on my article compels me to say that I have a special and extensive knowledge of the construction of Titans and other developments of crane work, and should, therefore, be qualified to write about them. None know this better than Stothert & Pitt.

I am, Sir, yours faithfully,

JOSEPH HORNER.

17, Vernon Terrace,
Twerton-on-Avon, Bath.

January 21, 1899.

These letters explain themselves.

PHOTO BY BARRAUDS, LONDON

Jeremiah Head

LATE PRESIDENT OF THE INSTITUTION OF MECHANICAL ENGINEERS OF GREAT BRITAIN

CASSIER'S MAGAZINE

VOL. XV APRIL, 1899 No. 6

ENGINEERING IN AFRICA AND THE FAR EAST

By J. M. Nisbet, Late Mathematical Instructor at the Northern China Government Training College

IN the service of the Portuguese in Africa, about twenty-five or thirty years ago, the title "British engineer" seemed to imply that its possessor had the mechanical knowledge and ability to work at marine engines, sink artesian wells, erect distillery plants, mount sugar and coffee machinery, dig a fresh water canal, in short, be a mechanical Crichton. It is laughable, but true; and, somehow, the British mechanics of those days, with characteristic modesty, accepted the compliment paid them, and,—if only by silence,—admitted that the credit was not undeserved.

About that time, a few official and influential gentlemen in Portuguese West Africa had speculated in machinery for the manifold purposes above mentioned. Some of that machinery had reached the nearer destinations, but was not erected; some of it was well on its way to more distant parts, and other portions had but barely started on the way to far distant districts where steam and machinery had never been heard or dreamt of.

All this had been going on about two years previous to the writer's arrival on the scene. It thus came about that, though engaged as a marine engineer, he was very speedily directed to proceed overland from St. Paul de Loanod to Dondo, the highest navigable point of the River Coanza, and thence to Cazengo, about 80 miles further inland, touching on the way at a number of other points, at all of which he was to undertake the erection of the various machines on the estates of the speculative gentlemen before mentioned. No European accompanied him, but he had a bodyguard made up of his attendant and interpreter, a Cabinda boy, sixteen carriers, and a motley crew of native experts in mechanical arts.

After erecting sugar cane crushing and distilling machinery at Bruto, sinking several artesian wells, and erecting other cane crushing and sugar machines

AFRICAN WOMEN WORKING IN THE FIELDS

THE CHINESE WALL NEAR TIENTSIN

at Massangano, I began my long march into the interior via Dondo to Cazengo, where a considerable amount of various machinery for the treatment of the coffee berry had to be erected, together with engines, boilers and workshop plant.

On the way we came up with some of the carriers conveying machinery to Cazengo. Some of the heavier portions and the boilers (in sections) were piled on the banks of the river Lucalla. It was impossible to get these portions over the native bridges. We had, therefore, to get these pieces abreast deeper water and raft them across. The boilers were too clumsy in section to render this mode of conveyance practicable, and it was decided, therefore, to put them together and float them across.

During this tedious delay my factotum was using the rod freely amongst the men. On questioning him as to the reason, he hesitated a bit, but managed to convey to me that the carriers thought me " off," significantly touching his head,—" Expecting to get that thing to sail." To see the boilers floating over was a revelation to them, and was the occasion for a night's singing and dancing.

Ere I had got thus far I found that the native workers with me, the bulk of whom had never before handled a tool or seen a steam-engine or machinery of any kind, turned out to be fair, practical workers. They were ready to acquire the knack of manipulating tools, apt to retain an idea when once it was clearly demonstrated to them in a practical way, and took pride in doing any work sufficiently well to pass muster, or, better still, merit recommendation.

They were inclined to take a lazy fit occasionally, but not more so than the tropical heat almost demands both from native or European.

Four days later, nearing "Colonia Prototypo," as the estate was named at which the machinery was to be erected, we were met by Señor José Albino Sueroz, the proprietor, and his son-in-law, Commandant Antonio Gomez.

Commandant Gomez was the first European to meet and welcome Livingstone on his journey from Central to West Africa, and his plain house afforded the first taste of European civilisation and comfort, not to mention the four-posted bed, Livingstone had enjoyed for nearly fifteen years. Both Señors Albino and Gomez were never tired expressing their good fortune and pleasure in meeting the great traveller.

While fitting up machinery there, I heard from the proprietor of the estate of the iron ore district further to the interior, and of the native villages of iron workers and smelters there, and how these iron workers supplied most of the native requirements of the provinces of Benguella, Mossamedes and Angola with arrow heads, hoes, knives, fish-hooks, and such like. When almost giving up hope of being able to visit this iron district, accident favoured me. A 3½-inch roller shaft of one of the mills broke off at the outer journal. After

CUTTING A PASSAGE THROUGH THE WOODS

making several ineffectual attempts to weld on a new end at our own smithy fire, the only alternative was to either send the shaft on to Loanda for repairs, and so delay the whole work about six weeks, or try the native iron-workers' district, two days' journey distant. The latter was decided upon.

ON THE MARCH

On arrival at this place, I found a village of about a hundred scattered huts, almost hidden from one another in dense brush-wood and cactus plants, wild orange and banana trees, and cocoanut and palm trees. On nearing the village, little streaks of smoke could be seen, and the tinkle, tinkle of hammers could be heard, accompanied by a humdrum song. On approaching, every inhabitant seemed to be a blacksmith; children carrying charcoal; elder children, men, and women blowing the bellows, accompanying and timing the stroke with measured chant and much apparent banter; but, whether smelting iron or forging hoes or other simple agricultural implements, fish-hooks, arrow heads or knives, the stock in trade was essentially the same.

The bellows looked like two large,

rude golf sticks, secured together, the stick proper being about 3 inches in diameter, and the striking end about 10 inches in diameter by 8 inches deep. A better comparison might be imagined if two banjo heads were knocked to one side, one to the right and the other to the left of the finger board, and strapped together. The blast hole, 1 inch in diameter, ran up the length of the finger board, and the open end of the banjo head had loose, soft pigskin strapped around it to give a lift of 6 inches or thereabouts, there being a centre knob to hold on by; a rude inlet valve, consisting of a square frame and soft leather facing, was at the outer rim, and a like outlet valve at the bellows end of the finger board. Each stroke gave an effective air flow of about 400 cubic inches, and each blower made from 30 to 60 strokes per minute.

These bellows betokened probably the improvements of some half-caste Portuguese, as other bellows have no valves, but blow into an enlarged funnel-shaped tuyere, drawing the air up and down the tube alternately. These latter are most common and very inefficient. Monteiro says he never saw any other bellows than the latter, and he identifies them with the bellows of the ancient Egyptians.

A NATIVE AFRICAN BRIDGE

The fireplace was, in all cases, a simple cavity, scooped out of the ground, and the fuel was charred wood. The smoke, noticed in approaching the village, came from burning wood heaps. Knives and spear or arrow heads were incased in clay cases, containing charcoal and some substance,—I could not learn what,—and baked in the fire for a number of days, and then the fire was allowed to gradually die out. Unquestionably, therefore, the natives must have had some knowledge of a cementation process, or an approach to it, for the improvement in the quality of their iron. Final tempering was effected by immersion in palm oil. Whether smelting or forging, the furnace was the same, viz., a hole scooped out of the ground, charcoal used as fuel, and a mixture of clay added as a flux for smelting. The heaviest smeltings I saw in block were not more than 4 or 5 pounds in weight; but much heavier ones were occasionally undertaken, as the heavier anvils were apparently smeltings run into moulds, and were afterwards bedded into blocks of hard wood, weighing about 28 pounds.

Malleable iron was derived from the castings by repeated smeltings, and finally by heating and reheating to a spongy mass and working under the hammer. I did not see this process carried through; but it must be a slow, tedious one, as I saw no native malleable iron lumps of any appreciable weight. I was surprised to find such a resemblance between the mechanism of our own fire tongs and those used by the ironworkers in Cazengo; but one of the Roman Catholic priests of Ambaca, whose acquaintance I made, assured me that they were entirely of native origin. In heavy smeltings a number of bellows surrounded the fireplace and led into a number of tuyeres, each bellows blowing into its own tuyere, and every three bellows leading into a central tuyere.

Now for my own job! It was a difficult matter to get the natives to undertake it, though they understood well

A STREET SCENE IN SHANGHAI

enough what we wanted, as I had the broken piece with me. Ultimately on offering 30 pieces of printed cotton, each 9 yards long, and 8000 blue glass beads, and a further promise of 30 pieces of cotton if the repair turned out a good one, and the journal,—after being turned,—was found without flaw, the whole village came over to my side, formed a syndicate, and began in earnest.

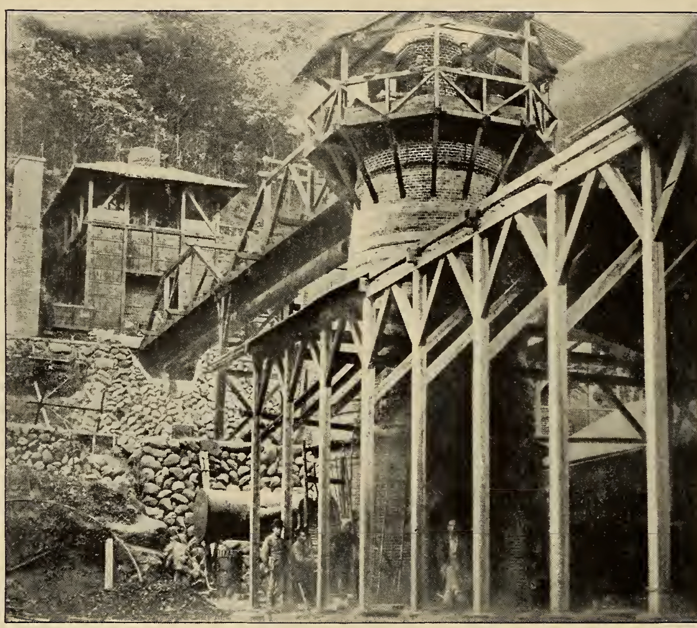
A large fire was got ready for heating the shaft, and men, women, and children relieved each other in turns at bellows-blowing. The weight of the shaft was supported by the overhanging branch of a tree. A smaller fire, with only two blowers, operated upon the native 1-ounce and 2-ounce nuggets of iron, and the two blacksmiths, acting as guiding spirits, began what very soon proved to be slab welding. At the end of the first day's work four such slab welds had been effected, and, at the end of four days, the shaft was long enough, but laughable to look at, of no precise shape. Its dimensions, however, were ample for my purpose. A head man was sent with us to Cazengo, and returned home with the cloth as promised, and more, the new end having turned up without flaw or mark of any kind. Indeed, it was doing its work, to my knowledge, eighteen months later.

In this part of Africa, iron stone is mostly obtained from Colungo Alto, malachite deposits in Cambambe, and also from the districts of Benguella and Dombe-grand. Monteiro tells us that, in 1861-'63, he found beds of copper ore yielding from 10,000 to 12,000 tons, some of this ore containing from a mere trace to over 100 ounces of silver per ton. Gold had been found beyond Cazengo and Colungo Alto at the river Lombige; but, unfortunately, not by me.

I was shown several large pieces of coal by the priest at Ambaca, which had been brought to him by natives of the district, but he could not say from what neighbourhood. The coal was of a friable and shaley nature. Some had also been found in Quissama, on the south bank of the river Quanza; but the Portuguese have only nominal pos-

session of this place, and the coal deposits remain untapped.

My next mission was to Ambriz, about 60 miles north of St. Paul de Loanda. After arrival there I heard of the malachite deposits of Bembe, which had been worked by a British company with Cornish miners. The accommodation for the men was very imperfect. The Cornish captain stuck to the home rule of day and night shift. Within nine months eight miners died, and the remainder, with one exception, had to be sent home. Long before this, the mines had been worked by natives, and from 200 to 300 tons had been brought into Ambriz each year. The mines belonged to several towns, and the natives were allowed to extract the ore on payment of a certain quantity to the chiefs of the respective towns. The British company had the mines on some such terms, I believe; and though they continued to work them with Portuguese and a few white miners, the whole thing came to grief, owing to the methods employed by unqualified and inexperienced men, and evasion of the just apportionment out of the quantity raised, payable to the native chiefs. Machines and everything had been left, and the mines forcibly abandoned. There was some romance about this story as told to me, and, having the leisure, I resolved to attempt the journey, in all about 130 miles inland from Ambriz.



A BLAST FURNACE AT NAKAKOSAKA, JAPAN

Joachim Monteiro, who engineered the mines, tells us that the malachite is often found in large, solid blocks; its extent has never been fully ascertained, no shaft being sunk beyond a depth of from 6 to 8 fathoms, and at the bottom of these shafts pure, solid malachite was found. He also thought that the country further to the interior will be found immensely rich in copper.

On my arrival at the mines I found several natives at work in little round pits, 3 or 4 feet in diameter, and of varying depth, not much over 12 feet. The descent and ascent were by means of wooden pegs, driven into the walls of the pit, and their only tools of labour, as far as I could see, were little hoes and spear-pointed knives about 10

inches long. The scene at the mines was desolate in the extreme,—deserted shafts, the British company's mining plant, engine and sawmill, standing silent and neglected,—monuments of misspent energy, broken trusts, rapacity, and unreasonable thirst for the attainment of personal gain. Looking back at the road along which I had come, I could not but admire the spirit of pluck and endurance that had brought this machinery through 130 miles of marshland, and forests of almost impenetrable cactus and tangled vegetation, over high plateaux and valleys, not to mention several rivers, and regret that this should be the result. My own troubles on the way to Cazengo appeared trifling in comparison.

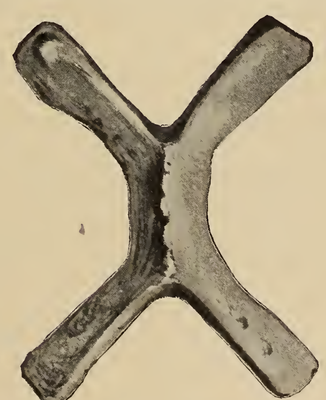
Native smelters of copper are plentiul, and follow the same process as that detailed in the smelting of cast iron; but in whatever part of Angola Benguella, and Mossamedes, the shape of the ingots of native smelting are always alike,—a cross with the section of metal in triangular form.

It may not be amiss here to tell of an incident not common to trial runs of machinery. On completion of some distillery plant erected at Bruto, on the river Quanga, as none of the natives had yet seen machinery in use, and but few of the children of the Portuguese, it was decided to have a gala day for the trial. All Europeans, quadroons, half-castes and natives for many miles around came to see the show. A native brass band was placed on a platform in front of the steam-engine,—a vertical one, with overhead crank. I had, previous to the start, warmed everything nicely through.

To the strains of the Portuguese national anthem, the engine began to splutter. I opened the drain cocks on the top and bottom of the cylinder. The music was fairly successful in deadening the noise, when unfortunately, the nipple of the drain pipe becoming detached from the cock, blew off, and the steam and water belched right into the centre of the band. Over went row No. 1 into the arms of No. 2, and they, in turn, into the arms of the drummers behind. Natives and band fled for their lives. As soon as the uproar ceased, the ophicleide was found resting vertically through a rent in the drum head, and the mouth of the flageolet was seen peeping out of the saxhorn end. No musician had carried his instrument with him further than necessary, and I was informed by the owner of the estate that some of the natives never rested till they reached their homes, some as much as 80 miles distant.

It is a long cry from West Africa to China; but the ground is more prosaic, and I am able to plunge right into the subject. China has three so-called arsenals, one near the River Peiho, at Tientsin; one on the Woosing River, above Shanghai, and one on the River Min, below Foo-chow-fow. These two latter are not arsenals in the proper acceptation of the word, but are rather government shipbuilding and engineering works.

The last being the most important, I will try to give some idea of its extent, and the nature of the engineering work carried on there. The buildings are spacious and substantial, and cover about 44½ acres, while the ground included within the arsenal walls is about 116 acres. The rolling mills occupy an area of about 45,000 square feet. Plates are rolled up to ⅝ inch in thickness; iron, square or round, up to 4¾ inches, and copper from 5-16 inch to 1 3-16 inches. The forges are provided with



AN AFRICAN COPPER INGOT

A VIEW OF YOKOHAMA

hammers from 6 cwt. to 7 tons, the largest of these being made at the arsenal. The fitting shop, boiler shop, and foundry each occupy a space of about 26,000 square feet, and the erecting shop proper occupies about 9000 square feet. It will thus be seen that the arsenal of Foochow is a workshop of no mean pretentions.

Let us enter the engineer's department as I entered it, and see what is going on! Two sets of engines by A. & J. Inglis, of Glasgow; one set of engines by Humphrey & Tennant, two sets of engines by Maudsley Sons & Field, and one set of engines by Penn are scattered over the floor, beautifully and carefully kept. A number of students are busy with note-book and measuring appliances, sketching various bits of each, and making faithful copies. Wonderfully clean and neat they are. From the year 1867 to 1874 fifteen composite ships had been built and engined in stereotyped copy of the above engines made by the Chinese themselves, not a departure from a 3-16 split pin upwards, and beautifully finished. The arsenal had been carried on by fifty-two Europeans up to this time. The head of all being a French gentleman, a goodly number of the Chinese students came to have a creditable knowledge of arithmetic, geometry, descriptive geometry, algebra and design; but, at the end of seven years' tuition, out of 105 pupils, 60 had to be sent away as incapable of following out the course of study, 6 died, and only 39 remained. Monsieur Giquel, in his farewell address at the end of his seven years, said that, despite these seven years of instruction, "the Chinese are not engineers, and China is not the country likely to make them so."

After this period the Chinese took

charge of the arsenal themselves, dispensing with Europeans other than mathematical masters, scholastic teachers, and drill instructors; and, up to my final departure from the country in 1887, the arsenals, as far as practical work was concerned, were lethargic and stationary, if not retrograde. Many laughable incidents were brought to my notice. A series of mishaps had occurred to a valve spindle on one of the Chinese cruisers, and I was required to examine the matter. It turned out that the vessel had broken four valve spindles within as many weeks, each cruiser, of course, having lathes and other tools for repair work on board. On inquiry of the chief engineer where he got the valve spindles, he assured me:—"Oh! that is all right; good stuft, sir; come see," and with all gravity he drew my attention to the fact that he had been using up 'tweendeck stanchions.

On another occasion a budding Chinese engineer asked me the favour of giving him "Something to do, not very easy." I asked him to give me the size of cylinders, high-pressure and low-pressure, and the size of shaft for an engine half the power of the one of which he had charge. Being a very smart fellow, he felt hurt at such a simple test. But, as I pressed the point, he, with ill-concealed offended pride, gave me two cylinders, exactly half the diameter of the original cylinders, and half the stroke. The crank shaft, in all particulars, was also exactly half the original diameter in body pieces and pins, and half the thickness in webs, and half the throw. The notion that half diameter was not equal to half area was a perfect puzzle to him.

Chinese government yards are not the places to find the best classes of Chinese mechanic. Repair shops in the British colony of Hong Kong, British shipbuilding and engineering works on the Woosung River, where merchant vessels of 4000 tons have been built and engined, and many other repair works have reared some native practical mechanics, in very many cases not one whit inferior to European workmen, especially in the capacity of machine men. Not a few have quitted the British shops and started works on their own account with fair success.

The ancient and high civilisation of China preclude the possibility of setting down the Chinese as fools. Their works, such as the Grand Canal, the Great Wall, the Bridge of Ten Thousand Ages, their agricultural implements, oil presses, and water pumps, not to mention their adeptness in ceramic art, and copper, pewter, and iron manufactures of purely native origin, all bespeak the possibility and probability of success in any mechanical art. The attainment of that success can be only a matter of time. But the Chinese are steeped in conservatism, and the upper classes are the great obstructors to the dispersion of that conservatism. All the high places in Chinese officialdom are open to competition; but the highest prizes are given not to the student of modern literature or letters, not to the best mathematician or modern scholar, not to the best scientist, but to the most advanced student of Chinese history. Study of any subject outside of history is, therefore, apt to be taken up in a disinterested, half-hearted manner. The Chinese worker is painstaking, if somewhat dull, careful in working out details, and painfully exact in carrying out orders. If the desire for isolation on the part of the governing classes were once broken through, and a demand for Western civilisation and intercourse were aroused, an awakening amongst the people would rapidly follow. But, rapid though the change of sentiment might be, it would require a century of time to permeate China's 300,000,000 inhabitants and bring home to their doors the benefits of such civilisation.

In 1875, when the first railway was built and operated in China (for 12 miles) between Shanghai and Moosung, the people, naturally, had to overcome some prejudices. But, after it had become an accomplished fact, the ordinary merchant class of natives acknowledged its usefulness, and patronised it daily in ever-increasing numbers, slowly at first, but in much greater ratio towards the end of the year, when the railway, by

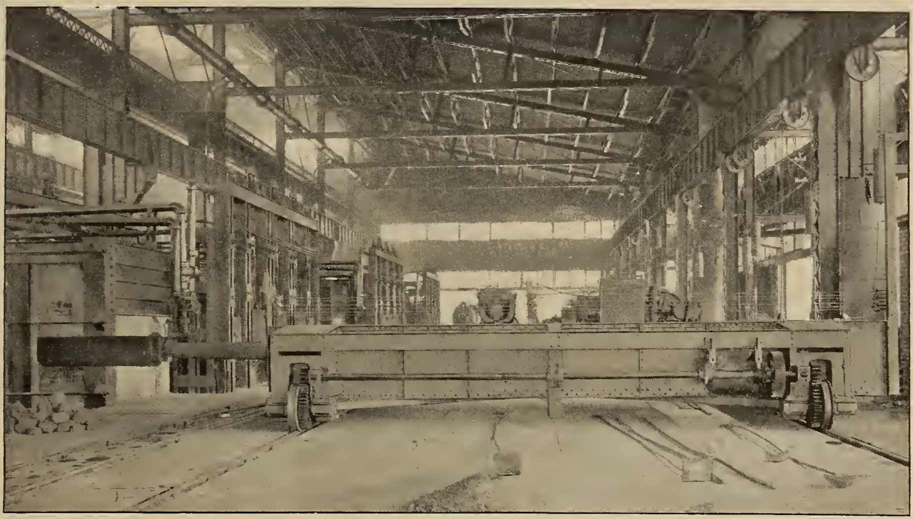
terms of contract, was taken over by the officials of the government. Within 48 hours of its being taken over, however, every vestige of it was gone, and the plant was shipped to Formosa.

In Shanghai some important businesses have been established and run by Chinamen and Chinese capital. For example, the very large ship-owning firm, the China Merchant Steam Navigation Company, glass manufacturing works, and other industries on a fairly large scale have sprung up. All European banks are checked in their financial dealings of discount, exchange, and bills by native Chinese. One hundred and one instances of intelligent callings and ventures carried out by Chinese could be cited. Can we, then, come to any conclusion than this, that there is nothing wanting in the Chinese to hinder them from becoming as expert in mechanical arts and sciences as we ourselves, were once the incubus of ancient conservatism lifted and the initiative in the awakening to come from, and be fostered by, the upper classes?

Japan, under its system of shoguns, or petty chiefs, previous to its present system of government under an emperor or mikado, and up to 1874, was much the same as China. The people, it is true, are of a happier, lighter vein, more genial, naturally more imitative, more combative, more self-assertive. But, practically, until their ancient conservatism was broken through, they were just as unapproachable and as hopeless of becoming imbued with Western aims as the Chinese. Indeed, on my first arrival in Japan, the moving commercial spirits in Japan were invariably Chinese subjects. Yet look at Japan to-day,—a naval power which no country can afford to ignore, a competitor with the Western world in mercantile navigation and in various lines of manufacture, a young people full of life, energy, and assurance, of belief in themselves and their own capabilities! Its principal ports, Nagasaki, Yokohoma, Kobe, and Osaka, were the principal ports open to European trade twenty-five years ago, and these are all, as yet, with the exception of one or two second-class ports for the shipment of coal.

Nagasaki twenty-four years ago had a small dry-dock, occasionally occupied, more frequently empty. Now the harbour has a dry-dock able to receive vessels 500 feet long, a second dry-dock for vessels up to 370 feet long, and very extensive additions to works, engine shops, boiler shops, and foundry. These works are now under able and enlightened native managers, assisted by European experts and advisers in each branch. A large business is done with all nationalities, and a large number of native coasting vessels are built and engined. From a British consular report lately issued, I find that in 1896 there were docked twenty-four war vessels of 63,104 tons, sixty-five merchant vessels of 109,608 tons, and thirty-six sailing ships of 21,047 tons. In the same year a steamer of 6200 gross tons, and of a speed of 12½ knots, was under construction, and has since been launched, and the material for a similar vessel was ordered from Europe, both these vessels being to the order of the "Nippon Yussen Kaisha" Steamship Company. Another vessel of 2500 tons was in course of construction, also a trading vessel (auxiliary steam) of 1540 tons, and finally a steamer of 1500 tons, building under Lloyd's special survey requirements.

With such an example of rapid progress before us, one cannot deny the possibilities of equally rapid progress in China.



AN ELECTRIC OPEN-HEARTH CHARGING MACHINE, BUILT BY THE WELLMAN SEAVER ENGINEERING CO., OF CLEVELAND, FOR THE CARNEGIE STEEL CO., PITTSBURGH

ELECTRIC POWER IN STEEL MAKING

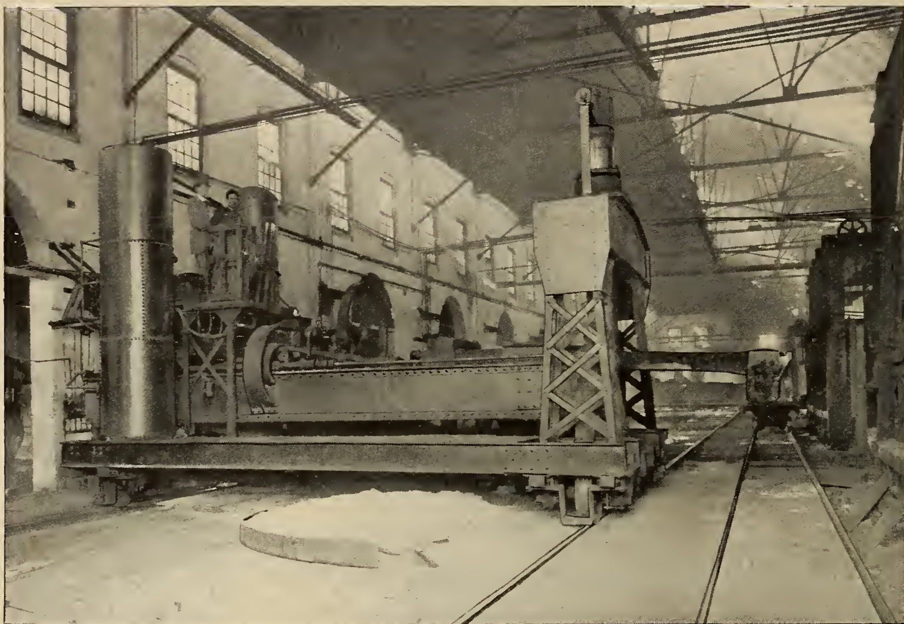
ITS PRESENT STATUS IN THE UNITED STATES

By Eugene B. Clark

IN the application of electricity to railroading and to long-distance transmission of power, such an abundance of skill and work has been spent that in both branches its use has come to be almost standardised. In telephony and telegraphy wonderful strides have been made and wonderful ones are still possible. In the fifth great field,—the application of electrical transmission in industrial establishments,—a quiet and unostentatious development is rapidly taking place that, while not bringing forth any engineering marvels, is of great importance, because its effect is to reduce the cost of manufacture.

The conditions existing in a rolling mill are particularly advantageous to the profitable application of electric power on a comparatively large scale. A steel plant, especially if it be a large one,—and the tendency is for them to increase in size even above their present huge proportions,—must necessarily extend over a considerable area, and contain many points, remote from one another, where power is needed. Consequently, there must either be a large central source of power with an extended scheme of transmission, or a large number of independent sources, or a combination of these two plans.

Practically, the combination is always used, but the tendency towards centralisation exists here, as everywhere. Therefore, the transmission of power becomes an important question to the mill operator. By reason of the many different classes of machinery in use and the widely varying demands, often very severe, made upon the machines, nearly



HYDRAULIC AND ELECTRIC INGOT CHARGING AND DRAWING MACHINE AT THE WORKS OF THE ILLINOIS STEEL COMPANY, SOUTH CHICAGO

every known method of power transmission is employed. Shafting, belting, and wire and hemp rope are in use to a limited extent; compressed air has its field; the slow and powerful stroke of an hydraulically operated machine is frequently required; steam pipe lines have been much employed; and oftentimes various combinations of these different systems are advantageous. But it is the transmission system which, in many cases, is the most flexible of all,—the electric,—with which we now have to deal.

The advantages of this system are manifold. Among the most important is economy, both with respect to the actual losses of power in the transmission line and to the operation of the system after installation. As regards the line loss, the electric is, without question, the most economical system under the average conditions and at the average distances involved in mill work, and, compared with some other systems, the difference is quite remarkable.

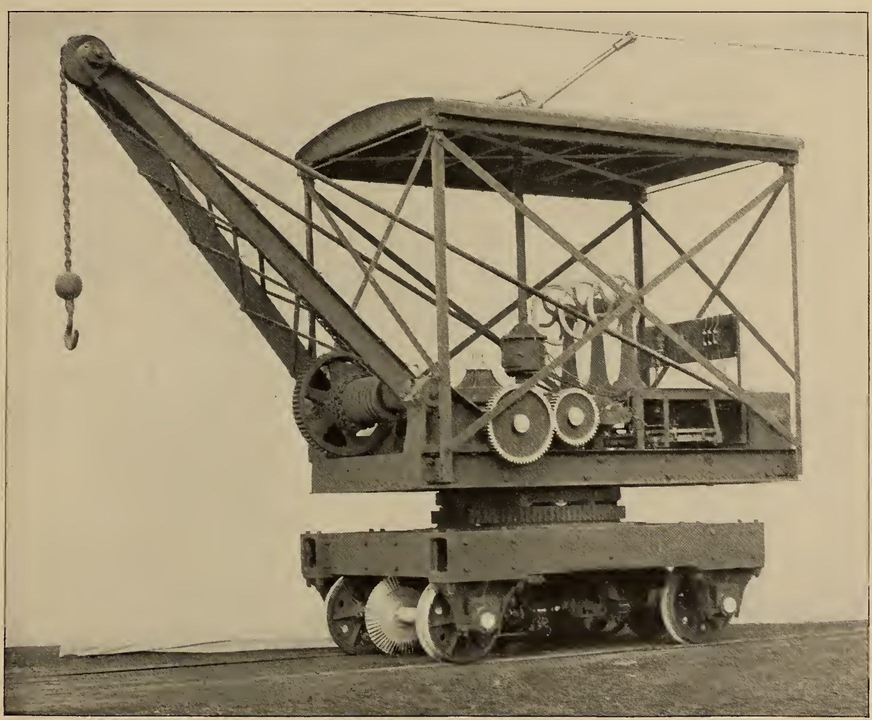
The writer has had occasion to investigate one case which brought this fact to light in an unusually forcible manner. In this instance the comparison was made of the relative costs of operating two " drops " (consisting of a mechanism for hoisting a 3-ton steel ball about 50 feet in the air and releasing it in order to break up " scrap " placed under it), one of which was operated by an electric motor supplied with current through about 1000 feet of wire, and the other by a steam engine supplied with steam through about 1000 feet of pipe. It was found that the cost of operating the motor was about 6.2 cents per hour, while that of operating the steam engine was about 35.4 cents. Of course, inasmuch as this service was intermittent, the electric current was used only while hoisting the ball, whereas condensation in the steam pipe was taking place continuously.

While this is an extreme case, it is by no means an unusual one; and we have still not taken account of repairs, supplies, attendance, and first cost, in all of which the advantage lies with the electric motor installation. The repairs

on a good motor, properly installed, not subjected to abuse, and carefully inspected at frequent intervals by a competent man, should amount to an almost negligible sum. On the other hand, we all know that while there are cases of engines running many months without repairs, it is unusual, and liable to result in a complete breakdown.

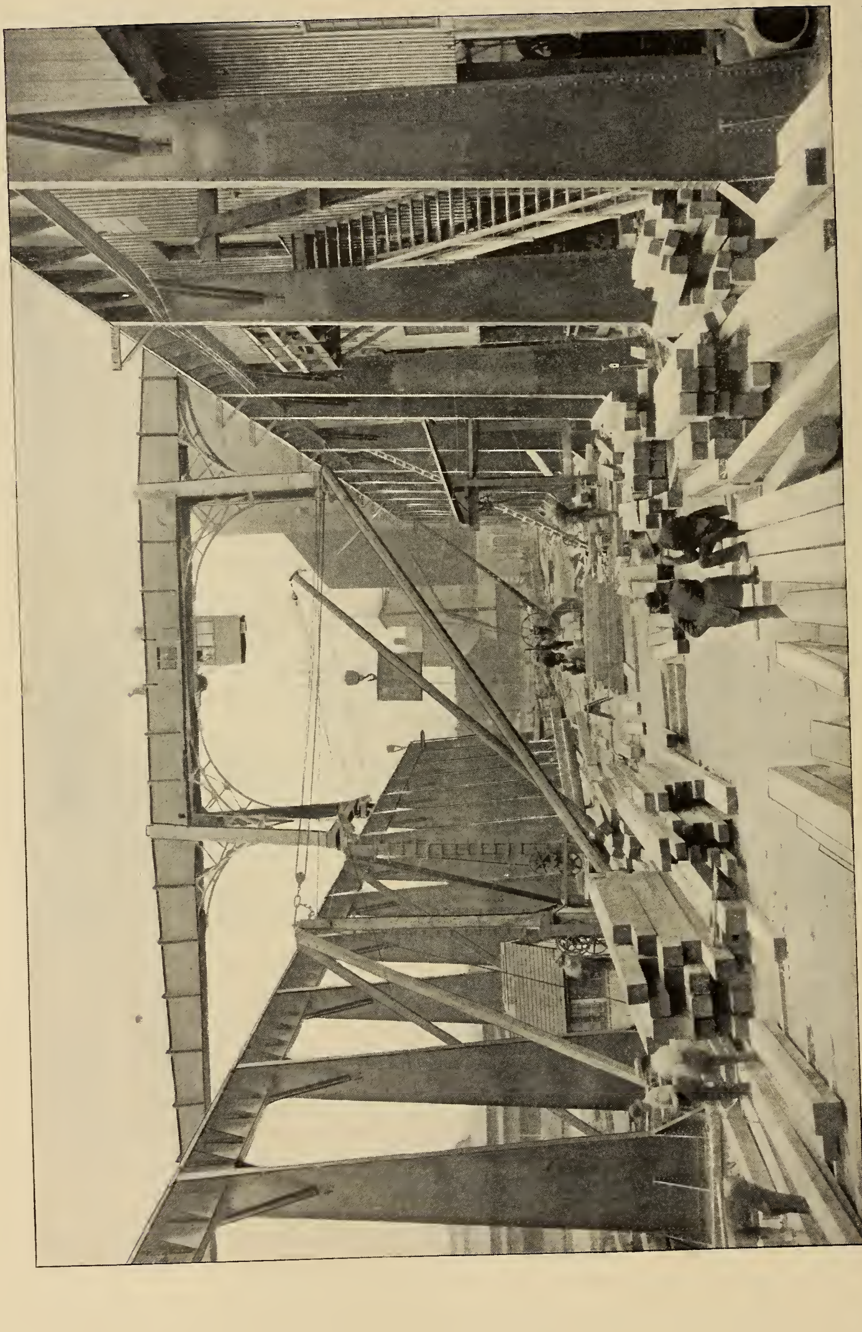
A motor, with its single moving part and only two bearings,—those self-oiling,—evidently requires less supplies, such as oil and waste, than even a very simple engine or other machine having valves and reciprocating parts. Again, in the question of attendance, the advantage lies with the motor. If it is well put in, and carefully insulated and protected by automatic devices, the cheapest kind of labour can operate it, while with an engine or other machine, no matter how simple, it is necessary for the operator to know something about its action; otherwise the repair bill will, indeed, be high.

Lastly, we find that in nearly every case power may be transmitted from the generative source to its point of application over a less costly transmission line when the electric current is the agent than when any other medium is employed. Any system of belting, shafting, or rope drive, and any pipe lines for steam, water, or compressed air, will, almost self-evidently, cost more than a couple of electric wires to transmit the same power, provided a rational voltage be employed. This lower cost will generally involve both items of the expense of the line,—labour and material.



AN ELECTRIC LOCOMOTIVE CRANE, BUILT BY THE MORGAN ENGINEERING CO., ALLIANCE, OHIO

Another great advantage of electricity in rolling mill work is the ease with which lines may be moved, or their capacity increased in case of desired improvements and changes. This point is of no mean importance, because advances in mill practice, especially with



AN ELECTRIC GANTRY CRANE, BUILT BY THE WELLMAN-SEAVER ENGINEERING CO., CLEVELAND, OHIO. OPERATED BY THREE-PHASE MOTORS

reference to improved machinery, are constantly taking place, and involve continual changing. And it is a fact that a large, and increasing, proportion of such improved machinery involves the use of electric motors, largely because of their ease of application to complex machinery, and the ease of manipulation of such machines when so equipped. The simplicity of construction thus obtained, even with machinery designed to perform "multi-motion" service, if the expression may be permitted, is remarkable.

This fact presents itself forcibly to the observer who compares a modern electric traveling crane with a rope-drive or square-shaft traveling crane of a few years ago, with its clumsy system of clutches. It was an expensive machine, costly to keep in repair, and slow in action, compared to a modern crane, and yet it was a labour-saving device that was hailed as a boon to those handling bulky material in shops, warehouses, and similar places.

Since the advent of three and five-motor electric cranes, many other machines, even more flexible in their fields of operation, have been designed and built, largely for use in rolling mills. Such, for example, are the various types of charging and drawing machines for placing ingots, slabs, and blooms in heating pits or furnaces, and for withdrawing them when heated; also machines for charging stock into melting furnaces, and for many other purposes, more or less special.

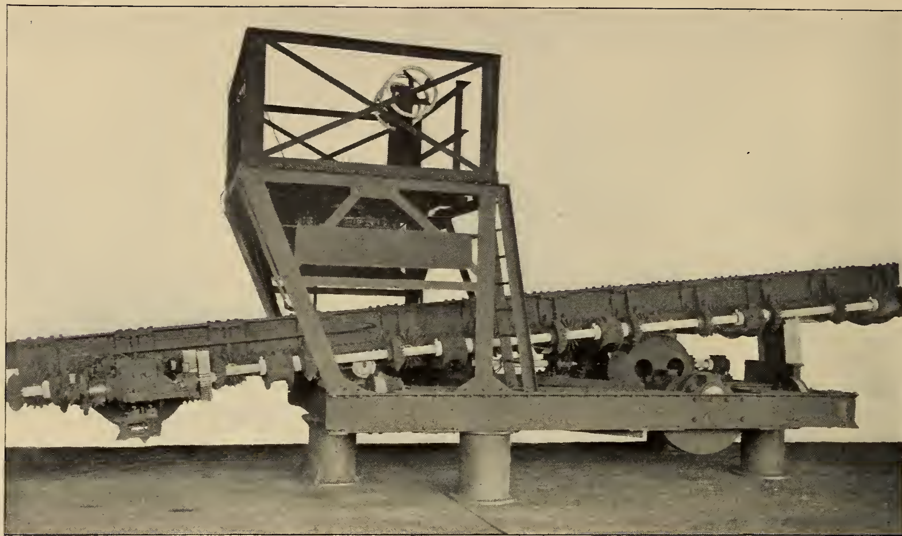
The several illustrations accompanying this article show types of the best modern construction of several of these machines, of which so many are now in use that they have become almost standard practice. The greater part of the development in this field, however, has occurred in the last two, or possibly three, years. In one of the largest steel plants, where between 7000 and 8000 horse-power of motors are in use, over one-half of that amount has been installed within the last eighteen months, and installation is still proceeding at the same rate.

The electric traveling tilting roller table shown in the illustration on page 446 is used for transferring billets from the heating furnaces to any one of three sets of rolls, and then delivering the billets to the rolls. When this was done by hand it took twelve men to do the work of one of these machines, and it was done much slower. Compare the amount of machinery contained in the ordinary locomotive crane, with that used in the electric "locomotive" crane shown on page 443, and then consider the saving in cost of repairs, in cost of power (the locomotive crane being a small independent steam plant), and in first cost of the machine!

Electric power needs no assistance in pushing its way into the field embraced by large manufacturing interests, such as steel making, and similar industries. Electric plants are a necessity, in any event, for lighting purposes, especially in those factories where work is carried on twenty-four hours a day, such as rolling mills, and at this stage of development of electrical apparatus, where light and power can be furnished satisfactorily from the same system, it is only a short step to increase the plant and have it supply power for transmission about the works.

This brings us to the question of the design and installation of the electrical system, including in this the station, with its generative apparatus, and the transmission lines, ending at the distributing apparatus. The conditions surrounding this problem, while not exceedingly difficult, are yet of considerable importance, for upon its successful solution depends the possibility of continuous operation of the mills. So intricate and interdependent are the various processes of manufacture of steel, as, indeed, is the case with most manufactured products, that a failure of the electric power, even for a short time, would cause serious delay, and might do great damage.

Imagine the feelings of a mill superintendent if the report, "Power off," should reach him just as he had a ladle containing fifty tons of molten steel suspended on an electric crane, or if his



AN ELECTRIC TRAVELING ROLLER TABLE, BUILT FOR MESSRS. JONES & LAUGHLINS, LTD., PITTSBURGH, BY THE MORGAN ENGINEERING COMPANY

urnace, containing a 50-ton heat, were just ready to tap and the bottom getting thin. It would not take long for his ladle of metal to chill, or possibly freeze, or for his heat to go through the bottom of the furnace. It must be the business of the designer of the electric system to absolutely prevent the possibility of such an occurrence by every known means and by special schemes to meet special cases. And he must remember that the chances of failure are not confined to the power station. They exist at every point of the system,—on the main distributing feeders; on the auxiliary distributing lines, such as run-way trolley wires; in the wiring on the machines themselves; and in the operating motors; and they exist in far greater degree by reason of the specially severe conditions ruling in a rolling mill.

The enormous forces under control are likely to become unruly at any time, and cause an explosion or a breakdown that may tear down the best-constructed line of wires. And there are always scale, dust, grime, and sparks in the atmosphere to " ground " or burn out the motors. Notwithstanding these drawbacks, however, a properly constructed electric system is more reliable for the transmission of power than any other in use.

The first question that meets the designer is, " Shall we use direct or alternating current?" There are arguments in favour of each system, but the bulk of the evidence points unquestionably to the use of direct current in the mills. The alternating induction motor is a simpler machine mechanically than the direct-current motor with its commutator and brush-holder, and in such places as a cement mill or foundry it would be preferable for that reason. In fact, the alternating-current motor would always be preferable, but not so with its speed controller, which seems to be a necessary evil in machine driving. A further disadvantage of the alternating system is the multiplication of wires involved, which, on a crane or similar machine, becomes troublesome. The direct-current motor is cheaper, more efficient, and just as reliable under proper treatment.

Another advantage attending the use of direct current is the possible use of a storage-battery adjunct to the station, —a subject which will be again referred to later. A mixed system being unde-

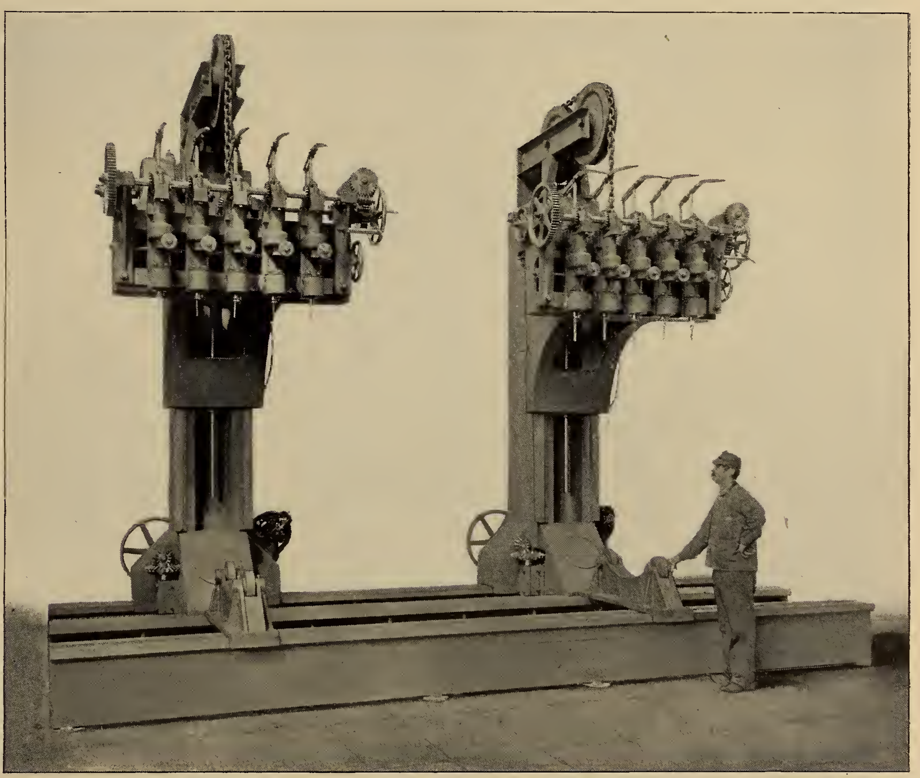
sirable, the question then solves itself by the choice of the direct current.

The voltage is the next point. It is, of course, desirable to have this as high as possible consistent with safety, on account of the economy of transmission. The usual factory voltage is 220, and most motors are wound for that amount. The next commercial voltage is that used on street railways, 500; but though more than 220 can be used in mills, it is not practicable to go as high as 500, owing to the danger from grounds. The writer believes 300 to be about the limit for rolling mill work, but as that involves special motors, it is best to adopt about 250, which will allow of the use of 220-volt motors.

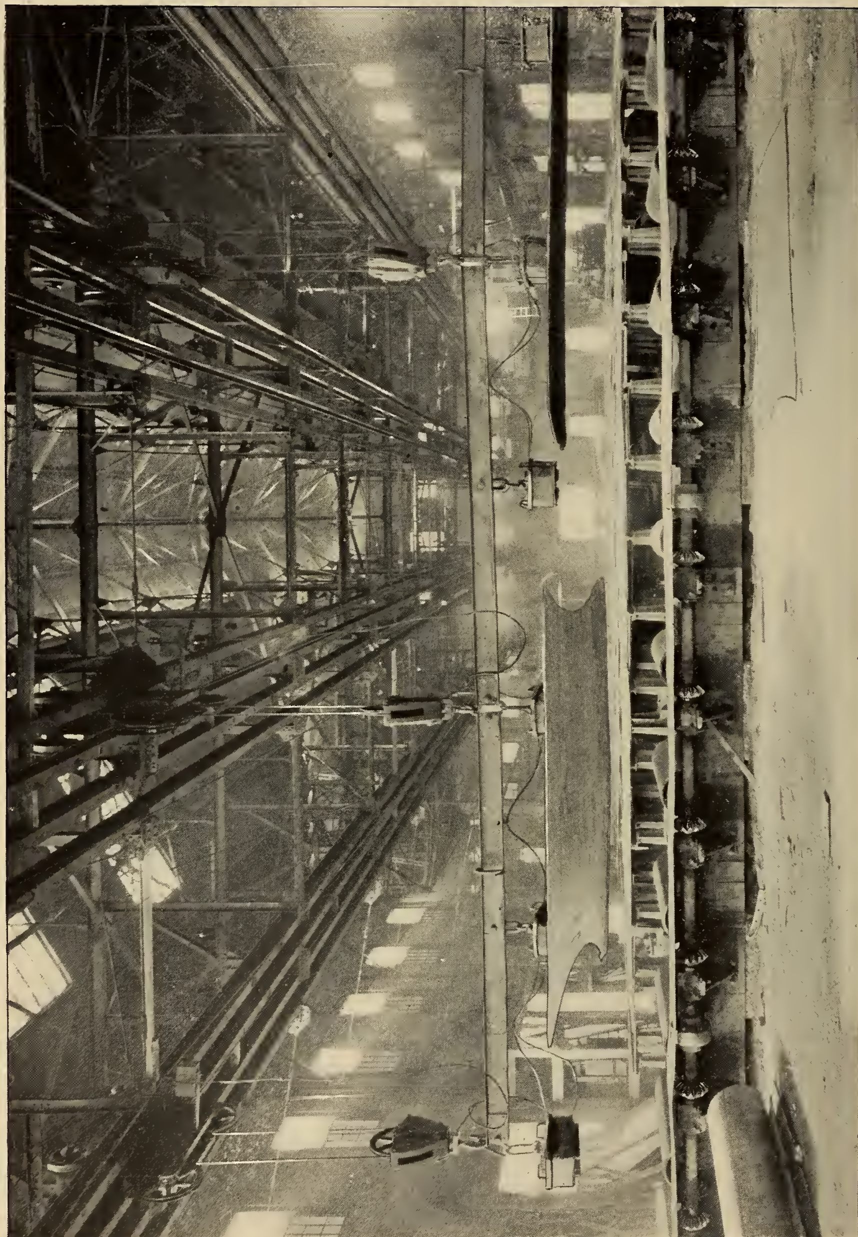
We now come to the most important question from an engineering standpoint,—the determining, in advance, of the most advantageous station equipment to operate the motors which it has been decided to install. This involves a study of the conditions surrounding each motor. Such study will result in dividing the work demanded into several classes:—

1.—Shunt motors operated continuously, either twenty-four hours a day, or at the same definite periods each day. This load is an easy one to estimate and to plot out on a theoretical load curve of the proposed station.

2.—Shunt motors operated intermittently, perhaps for considerable periods of time, but not at stated hours. This load is more difficult to figure, but if it represents a considerable amount of motor capacity, say 500 H. P., it will



A TEN-SPINDLE ELECTRIC DRILLING MACHINE, BUILT FOR THE SORMOVO COMPANY, OF NIJNI NOVGOROD, RUSSIA, BY MESSRS. WM. SELLERS & CO., INC., PHILADELPHIA, FOR DRILLING LONGITUDINAL SEAMS IN BOILER SHELLS FROM 3 TO 7 FEET IN DIAMETER



ELECTRO-MAGNETS HANDLING PLATES AT THE WORKS OF THE ILLINOIS STEEL COMPANY, AT SOUTH CHICAGO

be safe to figure generator capacity at 50 per cent. of motor capacity. It will, however, depend entirely upon special conditions.

3.—Reversing motors operated intermittently, such as are used on cranes, charging - machines, hoists, travelers, table-rolls, drops, and many machines for special purposes. This class includes the greater part of the motor installation, so far as capacity goes, and gives the fluctuating character to the power house load. The generator capacity for this load is more difficult to determine exactly, but it is surprisingly low. It is the writer's experience that if 1000 H. P., or more, of motors are installed in this class of work, the average amount of power absorbed by them, even when all working, will not be above 20 per cent. of their capacity, but that the maximum momentary demand may be as high as 75 per cent. Of course, it is possible for the demand to reach to almost any amount; but a very high peak in the load curve is so unlikely that it may be considered as provided for by the protective devices, or by the accumulator, if one be installed.

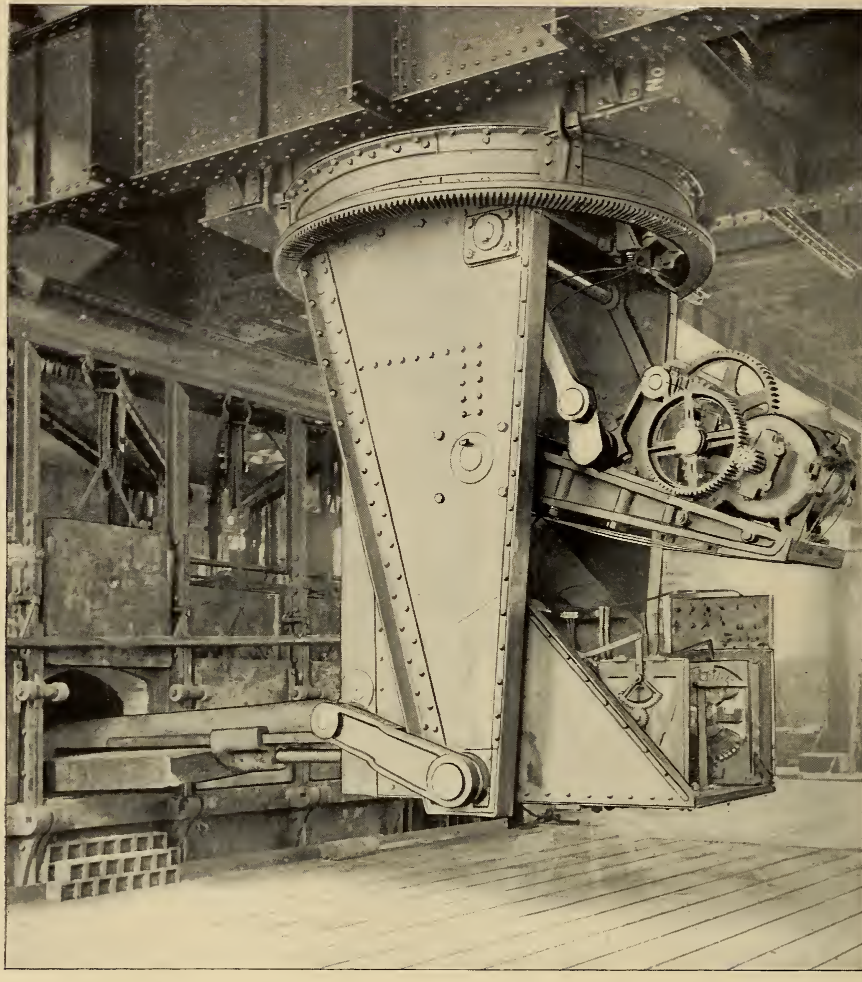
4.—Lighting and incidental uses. The load to be used for lighting is by no means an insignificant one, though, except for the fact that it involves more day load than in most lighting stations, it has no novel features. It is large, however, consisting, perhaps, of 500 arc lamps and 2000 incandescent, and must be reliably provided for, even in the face of numerous difficulties. A large portion of the arc lighting must, necessarily, be of the series kind; but the interiors of the mills may be economically and conveniently lighted by inclosed constant-potential lamps operated from the 250-volt system. The incandescent lamps should be alternating if much distance is to be covered, though, of course, lamps can be wired from the power mains also.

Among incidental uses may be mentioned one which is deserving of far wider application than it receives,—the use of electro-lifting magnets for the handling of plates, bars, and ingots. A plate is a most awkward piece of material to take from the top of a pile by the ordinary methods. It generally has to be pried up with a bar far enough to allow hooks, suspended from the crane block, to be placed under it, and when it has been placed in the required position the hooks must be removed. These operations require at least two men, and, if time be an object, four. How much simpler, quicker, and cheaper it is to lower a magnet down upon the centre of the plate, close the switch to excite the magnet coils, transfer the plate to its required position and open the magnet circuit to release the plate!

The objection is often raised that it is dangerous to handle plates in this way because the current may fail and allow a plate to drop on some one. In answer to this it may be said that a number of magnets have been in use in several large establishments for several years and the first accident from this cause has yet to be reported. The saving in labour and time when a plate-handling crane is equipped with an electro-magnet is almost beyond credence.

By investigating and plotting the probable load curve, the engineer is enabled to decide upon the station requirements, but he must keep in mind that there will probably be an increase in the demands within a short time from the completion of the station. Ample reserve power must be allowed in all cases, because the one essential condition to be kept in mind at all times during the design and installation is reliability of service. Not only should every protective device known to modern construction be employed wherever advisable, but extra precautions should be observed in many cases.

Reliability of service is of primary importance, with efficiency at low first cost a close second in designing and building the lines to carry the power from the station to the motor. This is a part of the work which, all too often, receives scarcely any special attention. Perhaps a poor grade of poles, carelessly framed, are set up to carry a



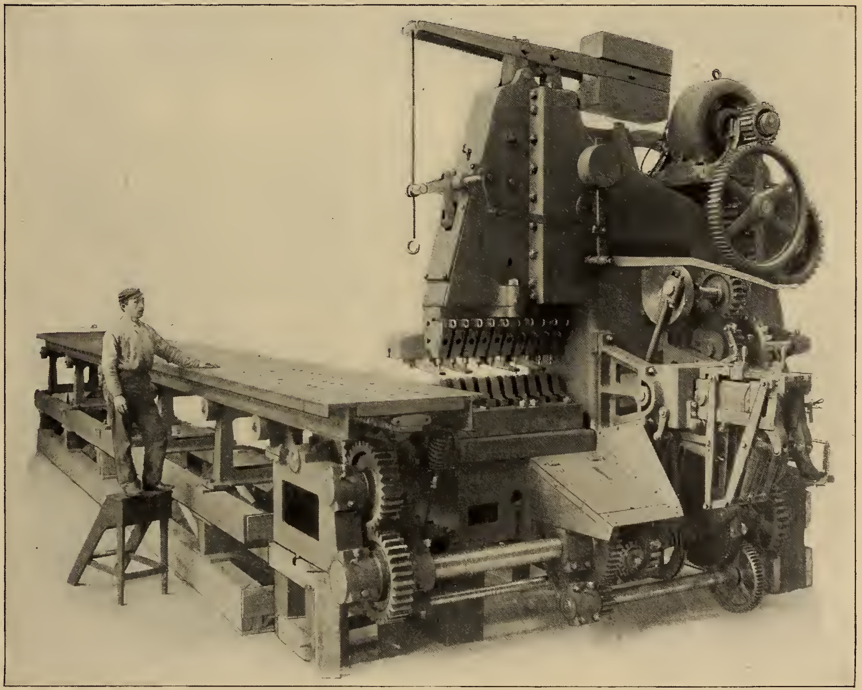
ELECTRIC CHARGING AND DRAWING CRANE, BUILT BY THE WELLMAN-SEAVER ENGINEERING CO., FOR THE BETHLEHEM IRON CO., CAPACITY 18,000 LBS.

great mass of comparatively small wires, leading to all parts of the plant, over roofs, through buildings, and liable, in many places, to injury from a dozen causes. As the demands increase, more wires are strung up until the system becomes so complex that it is always fraught with danger of interruption.

In designing a new plant, or remodeling an old one, it is possible to overcome such difficulties by anticipating quite closely the demands at various points and then wiring accordingly. Each mill can profitably be supplied by a separate power-circuit, leading directly from the power plant to a distributing switchboard in the mill, from which the apparatus in that mill may be supplied through as many separate circuits as may seem desirable. The main line to the mill will then be quite heavy, but generally not over the capacity of a single cable. In this way the copper required will be much less than would be required to run each circuit back to the station, for the capacity of each small line must be sufficient for the maximum demand upon it, and thus will frequently be in excess of re-

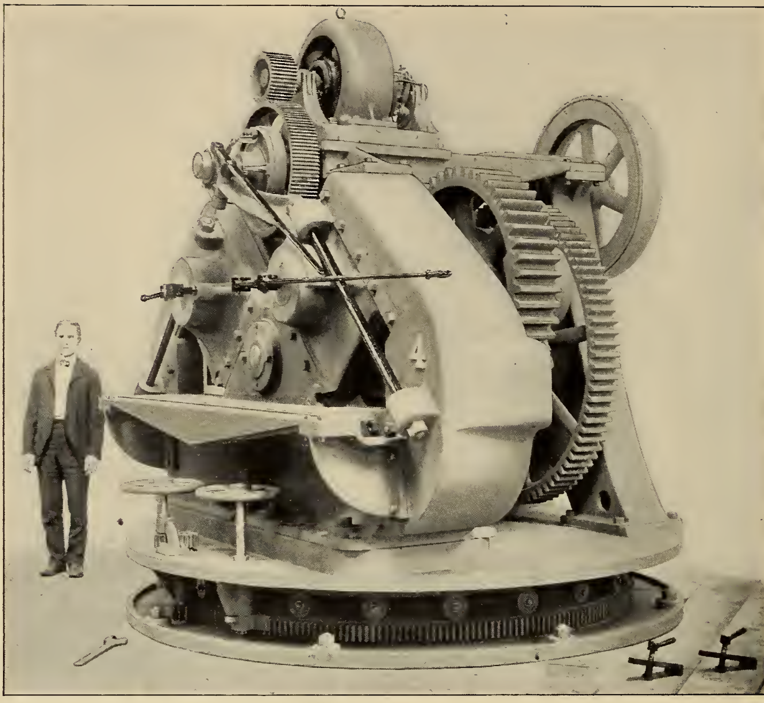
quirements for light loads. By having separate distributing boards, also, circuits may be temporarily cut off in the mills in case of trouble, without the delay of sending, or telephoning, to the power station.

The main mill circuits should be put up in the most substantial way possible, and in places where they will not have to be moved. All shunt motors should be provided with automatic starting-boxes which will return to "off" position upon the failure of power or upon an excessive overload on the motor. All distributing circuits in the mills should be fused rather heavily, or provided with time element circuit breakers. This also holds true of the main circuits to the distributing boards where they have the station board. And these circuit breakers must be of the double-pole kind, for, inasmuch as it is absolutely impossible to keep the system free from grounds, it may happen that a heavy ground will occur in such a way as to send the excess of current over the side of the circuit which is not protected. Then either the generator circuit breakers will let go or the ground will be burned off. Both of these occurrences are to be avoided. One means a temporary stopping of all power supply until the location of the fault can be determined, and the other means a damaged motor or controller, or possibly a burned-off trolley wire. If the generators are well insulated from ground, single-pole circuit breakers, well loaded down, will be sufficient. Lightning arresters should be freely used, with the usual care in placing and grounding.



A TEN-GANG ELECTRIC PUNCH, BUILT BY MESSRS. WILLIAM SELLERS & CO., INC., PHILADELPHIA, FOR THE PENCOYD IRON WORKS, PENCOYD, PA.

After all has been done, however, there is still a chance of some accident crippling the whole system, for only a short time, perhaps; but in that short time enough damage may have been done by the delay to pay for the one



AN ELECTRICALLY DRIVEN DOUBLE ANGLE SHEAR, BUILT BY MESSRS. HILLES & JONES, WILMINGTON, DELAWARE

remaining adjunct which can lend added safety and reliability to the system,—a storage battery. When installed and operated as a combined regulator and reservoir, the former function predominating, a storage battery plant may be made to produce a good return upon the money invested in it, both as regards the increased economy secured with its use, and as regards the insurance against shut-down which it provides.

With the usual size units in a large steel plant electric station, a storage battery, with a four-hour capacity about equal to that of one of the units, will cost about the same as the engine, generator, and boiler, with their foundations, and it will do just about the same work. It is not meant by this to say that it will generate current, but it will so equalise the load on the station, by absorbing the fluctuations itself, that one unit may be dispensed with and the other units run more fully loaded.

In this way a more economical condition can be produced and maintained with about the same outlay for equipment, and then we have, in addition to this, the possibility of carrying the mills over a period of delay such as might be caused by a broken steam pipe in the station or boiler house, or similar accident. In that event all but the most important work could be stopped and the battery would carry things along for quite a while.

To illustrate the character of a rolling mill load a couple of illustrations are given, showing actual observations taken at one of the plants of the Illinois Steel Company at South Chicago, Ill., U. S. A. The right-hand diagram on the opposite page shows a series of readings taken five seconds apart for a period of several minutes. The diagram at the left shows a chart constructed by plot-

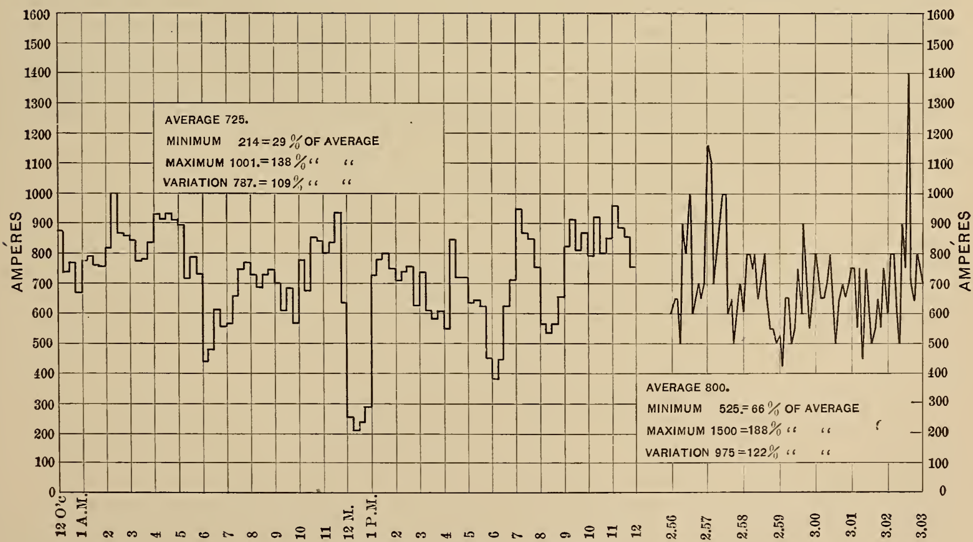
ting the average loads for 15-minute periods during the day of twenty-four hours. Readings were taken every ten seconds, and the average was obtained for each consecutive group of 90 readings.

While these were taken some time ago, and are, therefore, much lower than such charts would be now, they still represent the character of the load quite accurately, except that, as the average output increases, the variations increase in magnitude, though relatively to the average they decrease. From these general considerations it appears that a storage battery would often be most desirable, though it must be said that each case demands special consideration before it can be definitely treated. Certain it is that it will always pay to investigate.

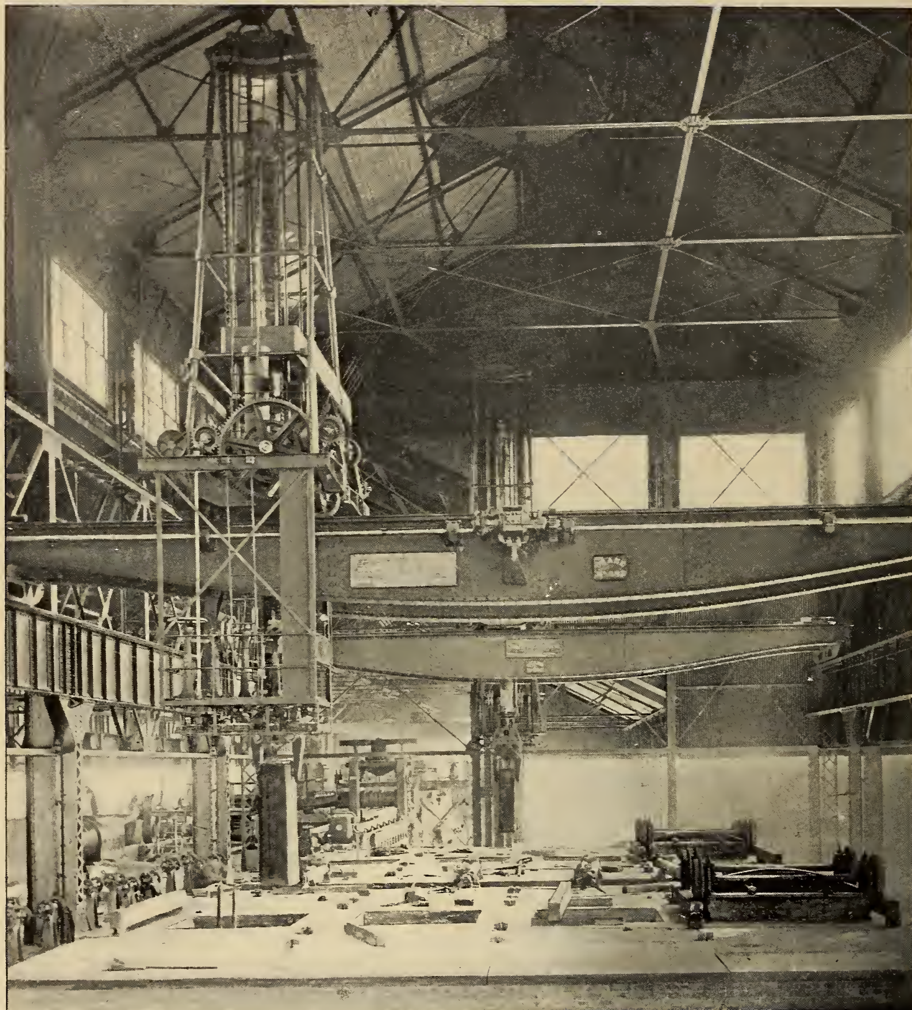
The foregoing considerations relative to the advantages of electric transmission, and to the design and installation, are not peculiar to rolling-mill practice alone. In many other manufacturing establishments just as much advantage will pertain to the use of electricity, though it is doubtful if any other concerns use it more widely than do steel plants. One large mill uses over one hundred electric traveling cranes alone. Perhaps we may best express it by saying that the foregoing remarks are general, applying to rolling-mill work as the most severe, and capable of modification to apply to other classes of work.

The question as to how far the field of electric power in rolling-mill work will progress is a difficult one to answer at present. The field was invaded only a comparatively short time ago. Six years ago very little was done except in the one particular of lighting. At that time motors and controllers,—the latter being the troublesome feature even now,—were not at a stage that could be called reliable. Designers and builders of rolling-mill machinery were not ready to give, nor were rolling mill managers willing to receive, electrically-operated machines. To-day such development has taken place that the builders find the motor the handiest tool they have, and the managers willingly accept it as a reliable device.

What the future will bring forth it is difficult to say. It is certainly just as true that motors are frequently urged for places for which they are not suitable, as that there are many places to which they are not now applied, but where they could be profitably used. To many, the small reversing engines operating the tables leading to large roll



A STEEL WORKS LOAD DIAGRAM



SOAKING PIT ELECTRIC CHARGING AND DRAWING CRANE, BUILT BY THE MORGAN ENGINEERING COMPANY, FOR THE EDGAR THOMSON CO., OF BESSEMER, PA.

trains are tempting targets for replacement by motors. It is truthfully urged that they consume an enormous amount of steam per horse-power per hour, and that they require too much repairing. But, after all, they work, and that is more than we could rationally expect an electric controller to do if we operated the tables as frequently and as severely through a controller and motor as we do now with some reversing engines. Of course, there are many roller tables where the requirements are not so severe as to preclude the use of motors, but to advocate the sweeping abolishment of reversing engines by motors is not warranted at the present stage of development of electric apparatus.

On the other hand, there are places for which motors are very seldom suggested, to which it is not at all unlikely that they will be applied in the future. Take, for instance, the enormous engines now used to drive roll-trains! They present a very unusual case of

extreme fluctuation of load. Tests have shown that the power demands may, and do, vary from 100 to 4000 horse-power within a fraction of a minute. Under such extreme variations the engine speeds change very considerably. The steam consumption per average horse-power is enormous, and in the aggregate becomes very important by reason of the large amounts of power involved.

There is no good reason why motors could not be built to replace these engines, and, being constructed of ample proportions and provided with large fly-wheels, made to run at the proper speeds and to give even better regulation than the engines. If several of them were operated from a station of large capacity, equipped with a storage battery, the cost of operating would be brought down markedly. The motors, after the first one, would not cost more than the engines now used, and the cost of installing and maintaining station equipment and motors would be less than the present cost of engines and boiler plants.

There are other cases that might be mentioned, but it is unnecessary to elaborate. Suffice it to say that the field is one which has developed from almost nothing, six or seven years ago, to an enormous extent at the present time. Who shall say that it has been covered now, when such golden opportunities are still visible on every side?

INDUSTRIAL IMPERIALISM

By Thomas Hitchcock

THE prominence in the market of the stocks of a number of recently-formed gigantic industrial corporations, as well as of those of other concerns of longer standing, has called renewed attention to the growing tendency toward the concentration in comparatively few hands of the capital invested in manufactures. Many have apparently seen in this movement a curtailment of the independence of producers of small means and a menace to the interests of consumers. Men of national eminence have publicly deprecated it and favoured measures for its suppression. The newspapers have joined in the cry, and denounce the great "trusts," as they call them, as enemies of the public welfare. To the economist, however, they are legitimate results of civilisation, and the natural outcome of the law that underlies all human development.

In a recent issue of the New York *Sun*, the writer discussed the subject from this point of view, and his remarks there are here substantially reproduced.

The dominant force in the physical universe is an attraction of its particles to one another, which has created out of widely diffused vaporous matter solid suns and planets. Our own solar system is held together by this force, and but for it would fly asunder and be dissipated into endless space. Air and water cling to the surface of the earth and form a continuous envelope around it. Minerals and metals cohere and serve useful purposes in proportion to the tenacity with which they retain their solid form. In living organisms, the assimilation and aggregation of substances go on continually, and whenever the process ceases, the organisms first decay and then die. Accretion is the mark of life, and disintegration the accompaniment and consequence of death. Neither a vegetable nor an animal can survive the destruction of its unity, and resists it to the utmost of its power.

History testifies that the same principle governs the growth and decay of

nations. Powerful empires have been powerful, not from the extent of their territories and the number of their inhabitants, but from the union of their parts under the sway of a central controlling head. China, for example, embraces an area of many thousand square miles, and its people are counted by hundreds of millions, but it is weaker than Japan, of one-tenth its size, because Japan is well organised and vigorously administered. In ancient times the Assyrian, Babylonian, Persian and Macedonian empires perished as soon as they were broken up. Greece fell under Roman domination because of the want of unity of its various republics, and Rome, in turn, ceased to be the mistress of the world when it ceased to be one organic whole. India, immense as is its area and its resources, was speedily subjugated by the British because it was divided into numerous petty States, each at war with its neighbours.

On the other hand, Great Britain itself owes its strength to having emerged from a succession of civil wars into its present unity. Germany, from a mere congeries of kingdoms, principalities and dukedoms, has recently been consolidated into one nation, and so has Italy. The United States for many years had been merely a string of feeble colonies, and, only since the suppression of the attempt to disrupt its union, has it attained the rank of a first-class power. When Benjamin Franklin put at the head of his newspaper the figure of a serpent divided into pieces, with the motto, "Join or die," he showed the sagacious perception for which he is celebrated. In obedience to the same principle his successors acquired Florida and the territory west of the Mississippi, and Americans are now on the eve of extending their dominion over Cuba, Porto Rico and the Philippines. Some denounce as "imperialism" this irrepressible growth, but they do it ignorantly.

Human industry has undergone a like development from the isolated and independent labour of individuals and families, into the organised activity of great factories and workshops. Spinning and weaving are no longer, as they were, down to a comparatively recent date, household occupations, but are carried on by multitudes of workers gathered together in mills equipped with machines which accomplish in an hour what formerly was the task of weeks. The rural blacksmith has ceased to forge horseshoes and nails by hand, but buys them ready-made. Every implement and tool the workman requires is turned out for him in quantities, instead of being made singly by slow and laborious processes. The result has been an enormous increase in the supply of the articles used in daily life and an equal diminution of their money cost.

From concentrating into great factories and workshops the labour previously scattered among thousands of little households, to further concentrating under single heads the numerous factories and workshops themselves, previously managed independently, is evidently nothing more than a step forward in the same path of improvement. The same saving of labour and reduction of cost that are secured by spinning and weaving in a factory, instead of in the homes of the spinners and weavers, are secured in a greater degree by combining a number of factories, as far as practicable, into one. In place of competition we have unity of enterprise. The cost of the raw material is reduced, and likewise the expenses of management and of distributing the product, and the industry, from being weakened by being split up among a number of conflicting owners, becomes an industrial empire, with all the advantages that imperialism possesses over divided sovereignty.

Against this industrial imperialism the complaint is made that it prevents men of small means from undertaking manufactures on their own account and compels them to become dependent for employment upon monstrous aggregations of capital, so that they are no longer free labourers, but slaves. The same complaint was made, and with as little reason, when what are now small

factories superseded the home workshop and collected the workmen under one roof, instead of leaving them scattered over the country. The poor man who used to make cloth, or nails, or horseshoes in small quantities gave way to the factory owner who paid him wages and profited by his toil. That the same factory owner now, in turn, gives way to the mammoth company owning many factories, is a hardship to him, perhaps, but to the community at large it is a benefit.

It is also said that the result of these imperial industrial combinations is to extort from consumers of their products higher prices, and, consequently, to secure for their owners excessive profits. This is not true as a matter of fact, any more than it is true that the weaving of cotton cloth in mills, instead of having it woven by hand on a small scale, renders it more costly to the consumer and unduly profitable to the mill owner. As the individual weaver by hand turns out less cloth by his day's work than the same weaver does in a mill, so a number of single mills produce less by the same expenditure of time and labour when run separately than when they are run in a combination. Instead of paying several sets of salaries, the combination pays but one; instead of forcing up by competition the cost of raw material, it buys it at the natural price, and, what is more, a smaller percentage of profits on the capital invested contents its members.

This last-mentioned item is one to which sufficient consideration is rarely given by even those who are friendly to the consolidation of industries now going on. The individual factory owner is, by common consent, entitled, as compensation for his enterprise and risk, to a sum which yields him on his investment a rate of interest far exceeding that which is paid to the idle capitalist, who relies for his income on the labour and enterprise of those to whom he lends his money. If, now, the factory owner can join to his own capital ten or a hundred times as much more, which other people are willing to lend him even at 5 and 6 per cent., he can do business at a vastly smaller rate of profit on the entire amount employed, pay 5 or 6 per cent. on the portion he borrows, and still retain for himself the 20, 30 or 50 per cent. on his own capital which he formerly gained. This is what the modern gigantic industrial combinations accomplish. The managers of them earn for themselves, indeed, princely salaries; but, since they pay on the capital they employ only 5 or 6 per cent., they can afford to conduct the business at a vastly cheaper rate, and sell their product at a lower price, than if they had only their own capital to work with. Their subordinates, too, who formerly were independent factory owners, being relieved of personal risk and responsibility, are content with a correspondingly reduced compensation, and this constitutes another saving of expense.

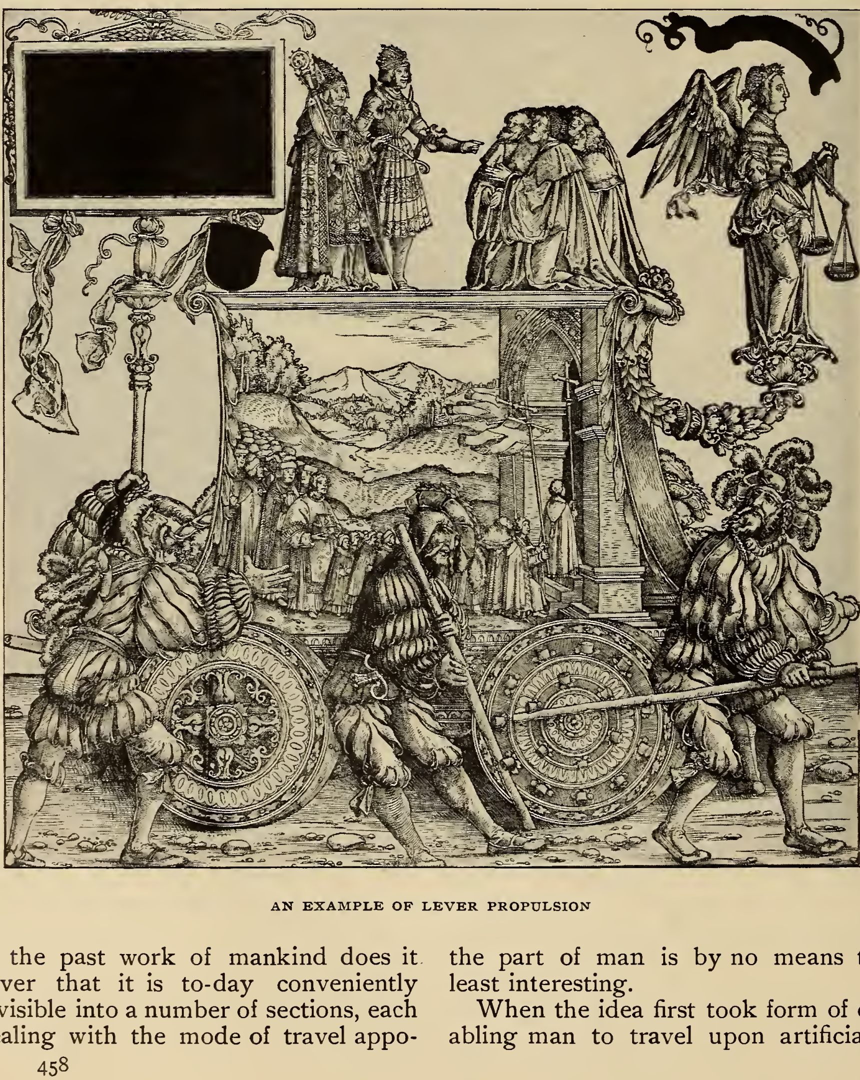
Respecting the supposed danger that these mammoth corporations may stifle competition, and exact from the community prices exceeding those which would be paid but for their formation, it is sufficient to say that the increasing wealth of a country and the prevailing low rates of interest for money, which threaten to fall lower still, are a sufficient guarantee against it. There are among us too many able men seeking employment, and too many owners of capital ready to lend it to them, for a permanent monopoly to be established in any branch of industry. Great as is the power wielded by corporations with great capitals, it is not greater than the power that can be brought against them whenever they overstep the limits of moderation. Competition can be suppressed only by making it hopelessly unprofitable, and the knowledge of this fact is a sure protection of the community against any ill effects of industrial imperialism.

HORSELESS CARRIAGES FOUR HUNDRED YEARS AGO

By A. R. Sennett, M. I. C. E.

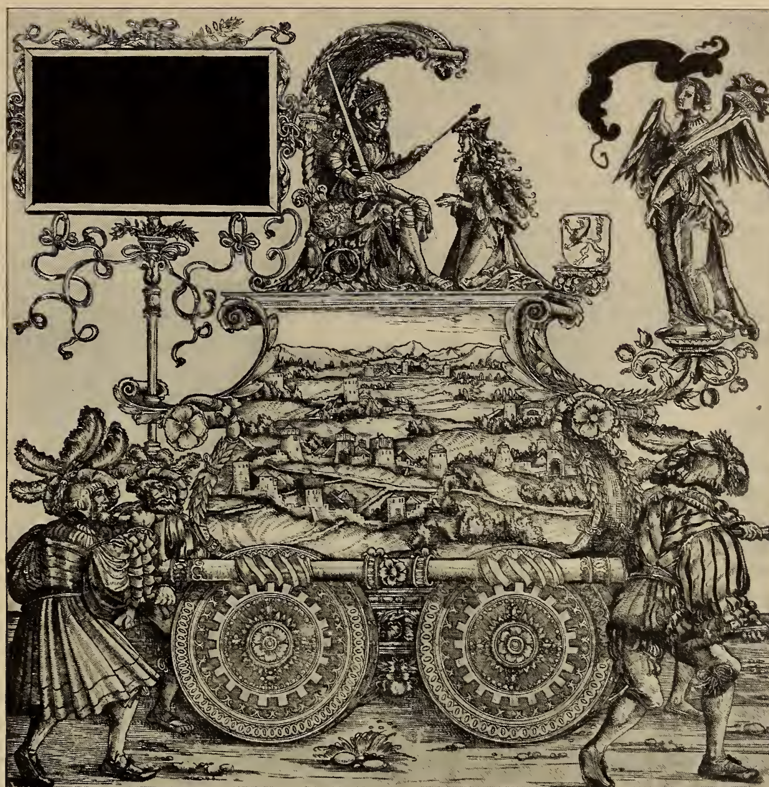
"God hath made men upright, but they have sought out many inventions"

THE history of mechanical locomotion is one of the most extensive chapters in the record of human invention. So large a field of the past work of mankind does it cover that it is to-day conveniently divisible into a number of sections, each dealing with the mode of travel apposite to specific conditions. Of these, that particular section relating to the propulsion of vehicles upon common roads by means of muscular effort on the part of man is by no means the least interesting.



AN EXAMPLE OF LEVER PROPULSION

When the idea first took form of enabling man to travel upon artificially



A WORM GEAR DESIGN

revolving wheels instead of upon his naturally reciprocating struts, we cannot say, nor is it known by whom the first attempt was made to put the notion into practice. Heliodorus, in the "Ethiopics," refers to a triumphal waggon used in Athens, which was propelled by men carried within it and acting upon certain mechanism provided for that purpose, whilst Pancirollus also alludes to such a chariot.

The history of the subject, however, is a singularly broken one; it has not followed the even tenor of the way of the steam engine, for example, and there have been reasons for this, the principal factor in producing such intermittency having been the state of the roads at various epochs. If we ask ourselves why it is that modern cycling has made such immense strides during the last decade, if we ask why such vehicles now weigh but a few pounds as against almost as many hundredweights, and if we ask why every kind of terrestrial locomotion is now accomplished at such a greatly enhanced speed, we cannot but give one reply,—the roads. Consequently, it is not surprising to find that the manumotive mechanisms put into the first road vehicles were chiefly added for the purpose of enabling them to surmount the difficulties offered by the most deplorable of highways.

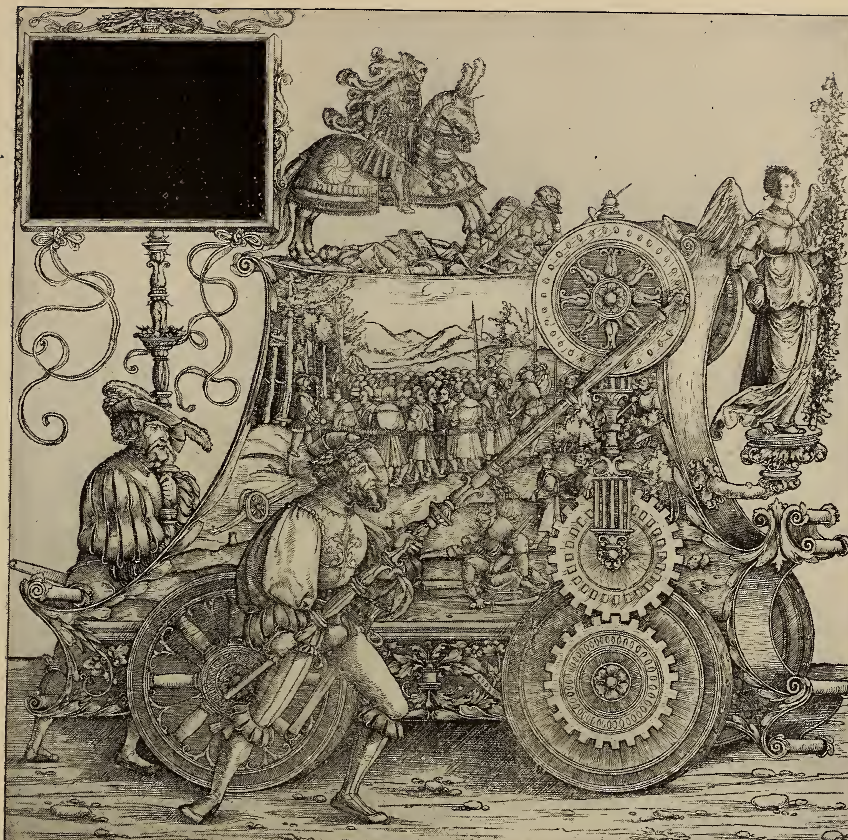
The very wording of perhaps the first patent granted for a muscularly-propelled vehicle,—that to Sir Ellis Leighton in the year 1667,—would go to show this:—"A Certeine Engine w^{ch}, Wrought and Disposed into the Bodyes and Carryages of Waggons, Chariotts, Coaches, and all Sorts of Things w^{ch} are used for Carrying of persons and Burthens from

One Place to Another by Land, will Facilitate to the Mõcon of all these Things, that it will extreamly save the Toyle and Labour both of Men and Horses, and Soe consequently pforme their severall uses with lesse Expense." At this period the average horse was a very powerful motor, a lady's hack then almost resembling one of the powerful dray horses of to-day, and as our forefathers, at that time, had not had any experience in the amount of power required to propel a road vehicle by means of their own muscles, it is not surprising to find them essaying to do so in connection with ponderous vehicles, quite unsuited to be thus metamorphosed. Thus, we frequently learn of attempts being made to modify the traveling chaise of the period into a manumotive carriage. In this relation we find, in the eighteenth century, one John Vevers, of Ryegate, in Surrey, interesting himself in " mechanical projections of the *traveling chaise* without horses."

It is a moot point whether the highly interesting muscularly-propelled cars designed for Emperor Maximilian of Germany (1459–1519), were ever constructed or not; certain it is, the designs for them were got out and the drawings executed by a man of no less fame than the celebrated Albrecht Durer. In a recent visit to his native town, the writer had the good fortune to purchase a complete set of these old and rare prints, and now has the pleasure to publish them for the first time.

A UNICYCLE

The one on this page looks, perhaps, more artistic than mechanical, yet it exhibits much ingenuity of design. Essentially it is but a single wheel,— a unicycle, in fact,— being muscularly propelled upon the mouse-mill or squirrel-cage principle. Within the gigantic " felloe " of this annular car was pivotally mounted an elaborate body, upon which we see ensconced the Great Emperor, to whom ladies of the court appear to be paying

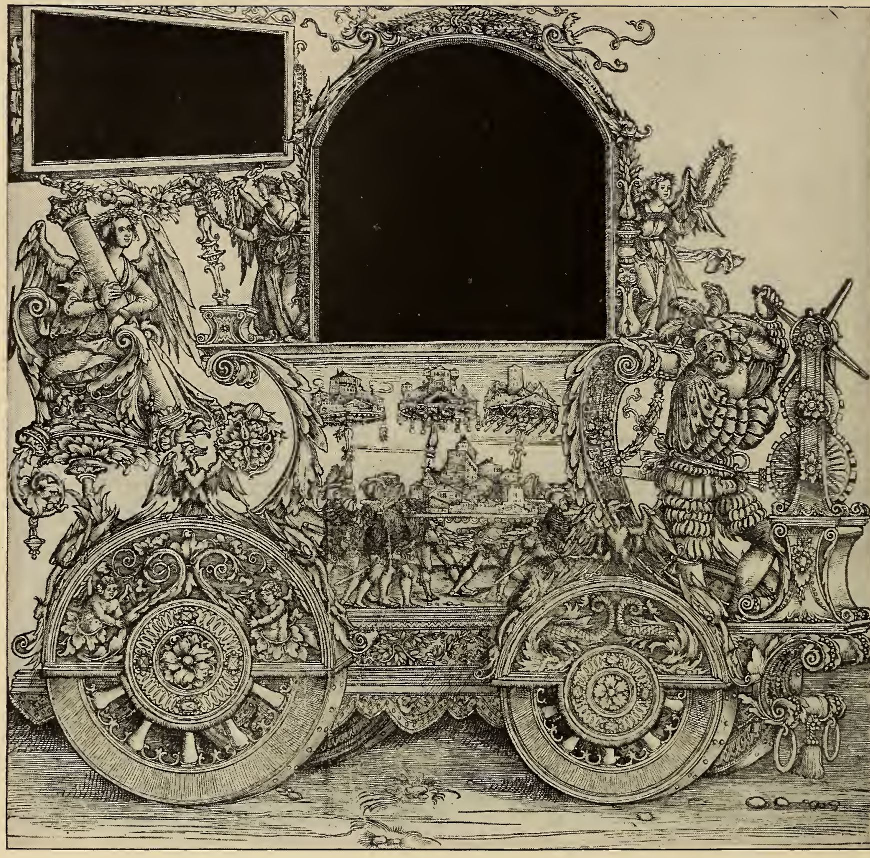


A COMBINATION OF LANTERN AND SPUR WHEELS

homage. The car obviously was counter-weighted, to prevent both its rotation and reversal. But how was it to be steered? There was the "rub,"—a "rub" which has cost many a modern unicyclist dear. The mediæval designer, however, got over the trouble with a gearing of commendable simplicity. The axletree was prolonged at one end, and to this prolongation was journaled a steering bar, to be manipulated by a sturdy henchman, whose livery, as well as that of the muscular propellers, whom we see climbing up the "everlasting staircase," was certainly both ornate and elaborate.

Neither can the vehicle shown on the opening page of this article be said to embody much mechanism, but there we see principles of increasing the effect of muscular exertion involved which must inevitably have been drawn upon long previously for the shifting of loads unmounted upon latter-day friction-decreasing wheels, and in this relation it is interesting to note that the artist was at fault in his leverages.

The illustration on page 459 introduces us to a mechanical combination as applied to a muscularly-propelled carriage which is surprising for more than a single reason,—surprising because one would hardly expect to find the screw or worm-wheel and pinion known at that date; more so at its being applied to such propulsion; and interestin as demonstrating and illustrating the oblivious bliss of the designer as to the ultimate possible speed his



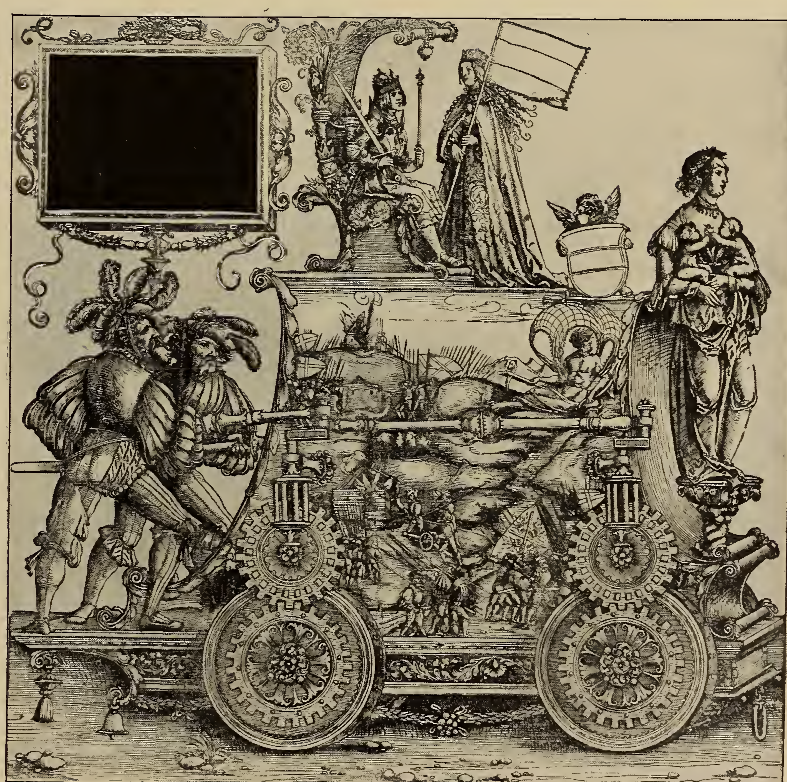
A MORE EFFICIENT TRAIN OF GEARS

carriage was destined to attain. Assuming the driving-wheels,—and they were all driving-wheels, so that no trouble from the nowadays much-discussed adhesion problem was to be feared,—to be each a yard in diameter, then the most energetic of propellers could not have advanced the car at anything beyond the certainly not alarming speed of a foot per minute, sixty feet,—the eighty-eighth part of a mile per hour.

On the preceding page we come to a vehicle entailing much mechanism, —much, indeed, which the ruthless pencil of the modern engineer would mark oft as superfluous. There we see a train built up of a crown wheel, a lantern wheel, a second lantern wheel, a second crown and spur wheel in combination, and finally, a spur wheel performing the office of driver upon the road-wheel. The sum total of the effects of this mediæval gearing would clearly have been to have increased, instead of diminished, the work required in a given time of the pleasant-faced motor whom we see busily engaged in thrusting and pulling at the ornamental connecting rod with which he is furnished.

So far, it will be observed, these muscularly-propelled cars have scarcely been such in the present acceptation of the term, from the fact that in each case the design has been of a nature necessitating the reactive strain being taken by Mother Earth, through the intervention of man's pedal extremities, for in neither case has the muscular motor

been awheel. Now, however, we come to a design (page 462) in which the reaction due to impulsion is entirely sustained by the peripheral adhesion of the wheels, which here, again, are all coupled drivers. Since it has, of late years, been proved that the transport of our own bodies awheel is far more economical, considering power expended, than afoot, we must say of this design that it is more scientifically correct as well as far more mechanically perfect than the one shown on page 400, for if we examine the gearing we shall see that its effect is virtually to add to the "man power," from the fact that the motion is geared down instead of up, as in the previous instances,—with the exception of the worm and pinion. Thus, a rapid reciprocating movement of the man-actuated connecting rods is reduced to a moderate peripheral speed of the road wheels. There appears to be no reason at all why this manumotive car should not have run,—or walked,—though the coupling link, hanging ominously from the front of the under-carriage, would seem to show that the designer had had his doubts upon the point.



ANOTHER LANTERN WHEEL DESIGN

Who is there among us modern engineers whose thoughts are not, from time to time, occupied with the problem of doing away entirely with the reciprocating motions in motor-carriage driving mechanism? Is not the name of rotary motor legion, yet, is it not a hard nut to crack? In the illustration on the next page we have it,—this rotative principle,—mediævally solved, clearly and practically, in a homo-propelled motor car, though when such shall be the case in a petrol-propelled

motor car the writer will, with Hibernian reticence, if not sagacity, refrain from prophesying. With this gear the car might easily have gone at the enhanced speed of 22 feet per minute, or 1320 feet, exactly a quarter of a mile, per hour.

One notices that the wheels of these cars were sometimes of the tympanum type, sometimes of the ornate spoke type, but always ornate, in striking contrast, indeed, to our timber-stick spokes or spider-web wire ones of this practical, all-speed, all-weight-reducing age of ours. Ornamental though they were, in the car shown on page 462 the designer seems to have desired to hide them, and this he did partially, as we see, by providing them with a semi-envelope, or paddle-box guard, highly ornamented. The gearing, too, he seems to have been at great pains to hide, as we are, in this nineteenth century. Whether it was of a materially modified form,—we observe that the lantern wheels have been extinguished,—and a more efficient train substituted, we cannot say; but it is fair to assume this from the fact that his "horse-power" has been reduced to a "man-power." Whether they may or may not have run, this display of sixteenth century muscularly-propelled vehicles is certainly of great interest to us, combining, as it does, much mechanical ingenuity and artistic taste.

THE ROTATIVE PRINCIPLE MEDIÆVALLY SOLVED

WATER SOFTENING

By W. N. Twelvetrees, M. I. M. E.

WATER PIPES CLOGGED WITH LIME DEPOSITS.

A GOOD deal is sometimes said about the advantages of pure water, but so far as drinking purposes are concerned, and quite apart from the abstainer's point of view, it is by no means undesirable that water should contain a certain limited quantity of foreign matter. Its bright and sparkling appearance is usually due to the presence of air and of carbonic acid in solution, and its flavour may be even improved owing to slight impregnation by mineral salts, acquired during its passage through the earth.

Absolutely pure, or distilled, water is not only insipid to the taste, but, offering an excellent medium for bacterial growth, rapidly becomes foul and musty. On the other hand, it frequently happens that too great a percentage of solid matter is contained in the fluid, which may render it either unpleasant or dangerous as a beverage, and may impair its efficiency for various domestic and industrial purposes.

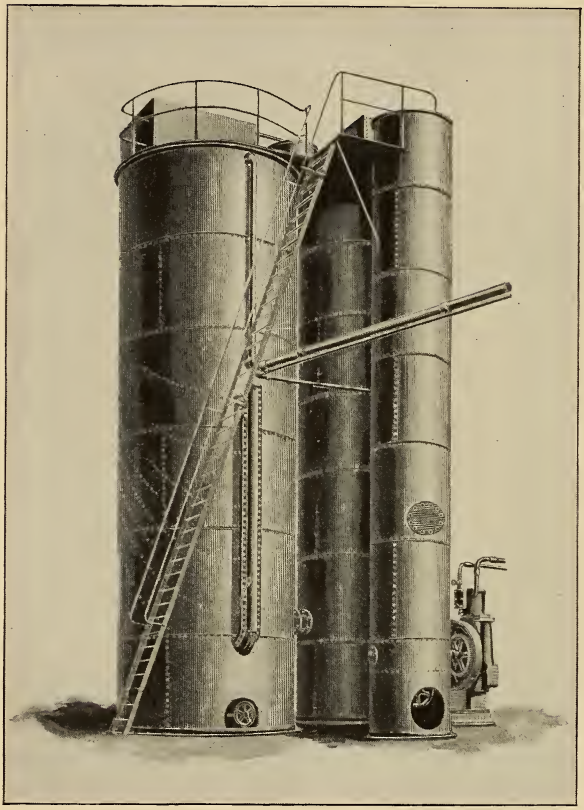
The general question of water purification need not now be considered, except so far as it is effected by softening processes, and the writer will deal simply with such extraneous matter as comes within the province of water softening apparatus.

Water, according to its source, contains in suspension varying quantities of animal, vegetable and mineral particles, which are found to be almost entirely deposited by softening processes. Included in the category of dissolved substances are earthy salts, chiefly bicarbonates and sulphates of lime and of magnesia, causing what is described as "hardness",—a term which, as ordinarily employed, is popularly understood to imply the presence of lime salts. Although the carbonates of lime and of magnesia are practically insoluble in water, they are readily dissolved by the aid of carbonic acid, nearly always present in water, and are thus converted into soluble, but somewhat unstable, bi-carbonates.

Such compounds as the latter are to a great extent decomposed by the act of boiling and constitute "temporary" hardness which may be removed by the application of lime in a suitable manner. Sulphates of lime and of magnesia, on the other hand, being of a more stable nature, give rise to "permanent" hardness, which is not eliminated by boiling and requires special treatment involving the use both of lime and soda.

Rain water, under favouring conditions, is almost perfectly soft, but is very seldom pure, and besides containing germs, dust, soot and other particles, holds in solution gases such as oxygen, nitrogen, carbonic acid, sulphuretted hydrogen, ammonia and sulphuric acid. All these foreign substances are acquired during its passage from the clouds to the earth. In London, examination has demonstrated that 100,000 parts of rain water contain 2 parts of sulphuric acid, in Manchester the

proportion is from 4 to 5 parts, whilst in Glasgow it rises to 8 parts. It will, therefore, be readily seen that rain water, in falling upon buildings, and in passing through the soil, may very soon become hard, by dissolving mineral substances such as mortar, limestone and rock.



A STANHOPE WATER SOFTENING OUTFIT. MADE BY THE STANHOPE ENGINEERING CO., LTD., LONDON

Reliable statistics from a large number of towns show that hardness has practically no effect on mortality, but upon industrial and domestic operations it exercises a very important and prejudicial influence.

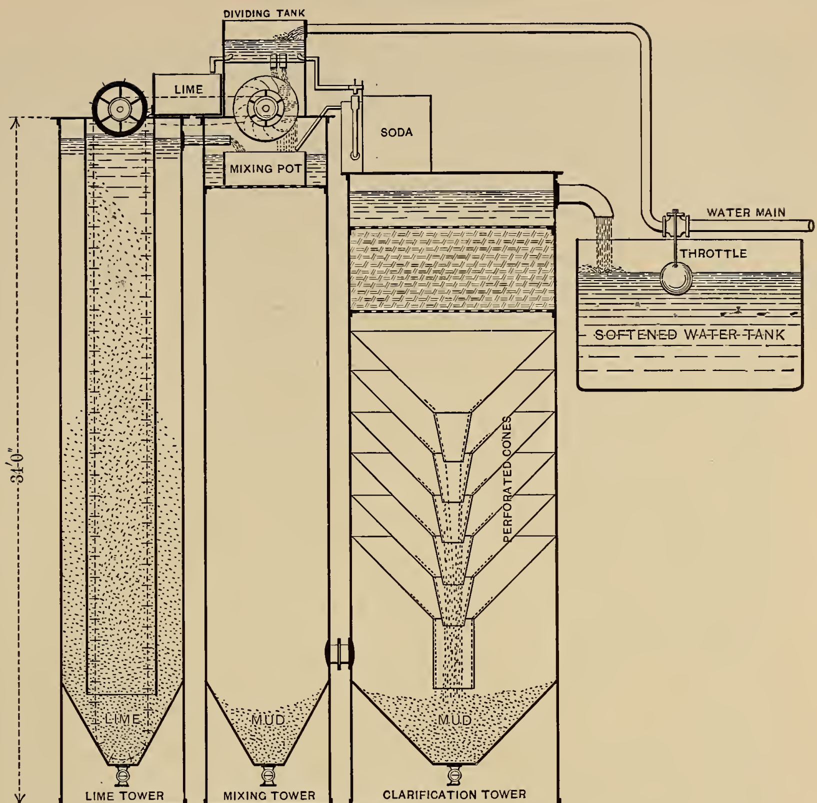
This is negatively, though happily, evidenced by the experience of Glasgow, where, owing to the substitution of Loch Katrine water for the previous public supply, it is estimated that the inhabitants save, in soap alone, the annual sum of £36,000.

Soft water is not only desirable for purposes involving the use of soap, but is indispensable in sundry arts and manufactures. The woollen trade of many large towns, for instance, would be seriously injured by a hard water supply, and other important industries would suffer in a like degree.

In the case of steam boilers, hard water is seen to constitute both a cause of expense, and an element of danger. A scale, formed of carbonate of lime, is sufficiently troublesome and expensive to deal with, but with it generally occurs a deposit of the sulphate, forming an exceedingly hard and crystalline crust, insoluble even at 300 degrees F., and very difficult to remove. Some water, in addition to carbonates and sulphates, contains chlorides, which, being decomposed by heat, produce hydrochloric acid, exercising a corrosive effect on boiler plates.

With the view of preventing the deposition of scale, chemicals are frequently used inside of steam boilers. Vessels of so costly and comparatively inaccessible a character are, however, inappropriately used for chemical operations which may, with advantage in every way, be conducted outside by the aid of more suitable appliances.

By the process of softening, water is rendered clear, colouring matter is removed to a considerable extent, and the greater proportion of organic matter and micro-organisms are removed. So important are its effects that, in a report to the Rivers Commission, Dr. Frankland recommends that all water companies should be compelled to lay down efficient water softening plant be-



A SECTIONAL VIEW OF A STANHOPE WATER SOFTENING PLANT

fore being allowed to raise additional capital, and he estimates the cost of softening to be somewhat less than £1 per million gallons.

It is stated on good authority that the carbonate of lime contained in the daily supply of London water equals 160 tons weight. A large proportion of this causes no waste; but taking a fair average, it may reasonably be reckoned that the price paid by Londoners, in soap, for the unsolicited presence of chalk in their water probably amounts approximately to £250,000 a year. That London should patiently suffer so enormous a tax is wonderful, especially when it is considered that the quantity of water which may be softened for one penny is capable, if delivered in a state of hardness, of wasting soap to the value of three shillings and eight pence.

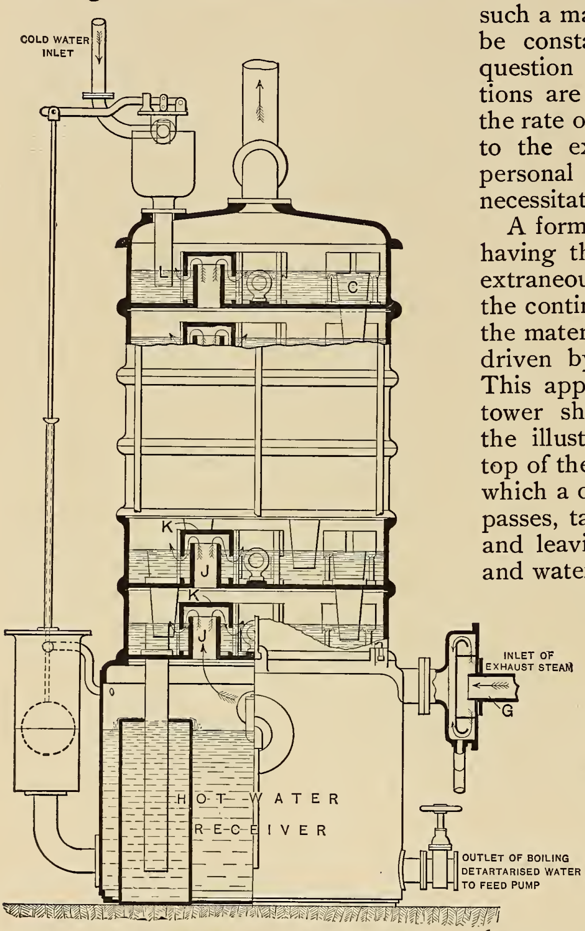
Turning now to the apparatus itself, we find it varies in size from the domestic model, suitable for the treatment of 50 gallons a day, to the gigantic installation capable of softening as much as 5,000,000 or more gallons in the same time.

In every case, the chemical part of the process is practically identical, but in points of mechanical construction the appliances, made by different engineering firms, naturally possess their own distinctive features, which are subject again to modification according to the purposes for which the apparatus may be intended.

Essentially all comprise chambers for the admixture of chemicals for the treatment of water, and for clarification. It is highly important that reliable means should be provided for the automatic regulation of the proportions of the reagents and of the water in accordance with results given by analysis.

In many instances filters are recom-

mended as useful adjuncts for the more complete removal of floating particles; in other cases filtering arrangements are included in the machines, whilst in one apparatus filtration is superseded by several other processes. In directing attention to various exam-



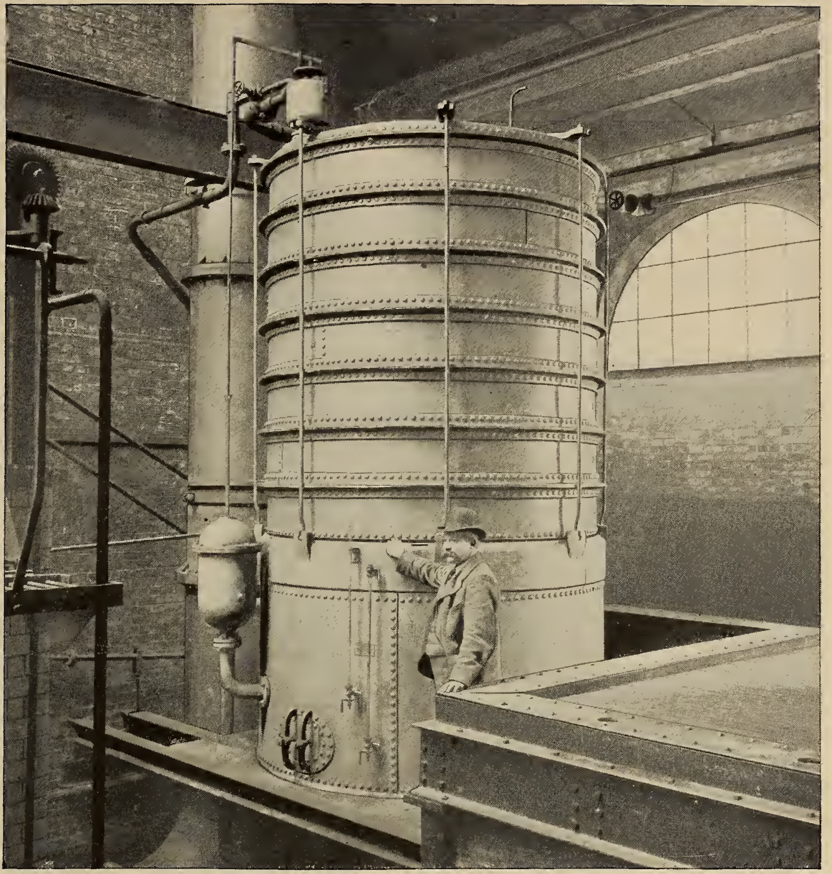
THE CHEVALET HEATER AND DETARTARISER. MADE BY WILLIAM BOBY, LONDON

ples of water softening plant, the order adopted, as a matter of convenience, has reference to external form, rather than to their comparative merits or priority of introduction.

In the Stanhope water softener the water for treatment is admitted to the softening vessel together with a suitable proportion of the reagent, and the makers very properly attach considerable importance to the efficiency of contrivances having for their objects not only the automatic regulation of the proportionate flow of both water and chemical solutions, but also the automatic and continuous mixing of the solutions in such a manner that their strength shall be constant. For the apparatus in question it is claimed that these conditions are adequately fulfilled, and that the rate of flow may be varied from zero to the extreme possible limit without personal regulation or attention being necessitated.

A form of the Stanhope lime-mixer, having the advantage of not requiring extraneous motive power, provides for the continuous and automatic mixing of the material by the aid of a water-wheel, driven by the water to be softened. This apparatus is situated in the lime tower shown on the left-hand side of the illustration on page 443. At the top of the tower is a lime tank, through which a defined proportion of the water passes, taking away with it pure lime and leaving the stones behind. Lime and water are discharged into an inner chamber extending nearly to the bottom of the lime tower. Inside this cylinder an endless chain is worked by the water-wheel, and is fitted with plates, after the manner of a chain pump, to insure the thorough mixing of the lime and water. The mixture passes under the lower end of the inner cylinder, and, ascending the surrounding annular space, arrives, saturated but clear, at the top of the tower, whence it overflows into the mixing pipe of the softening towers.

It is easy to arrange things so that the requisite proportions are duly observed. For instance, the weight of lime saturating a given weight of water is a fixed quantity (1 in 730), and the lime-water may, therefore, always be of definite standard strength. Knowing, by analysis, how much of this solution will be required for softening, the controlling valves of the apparatus are so

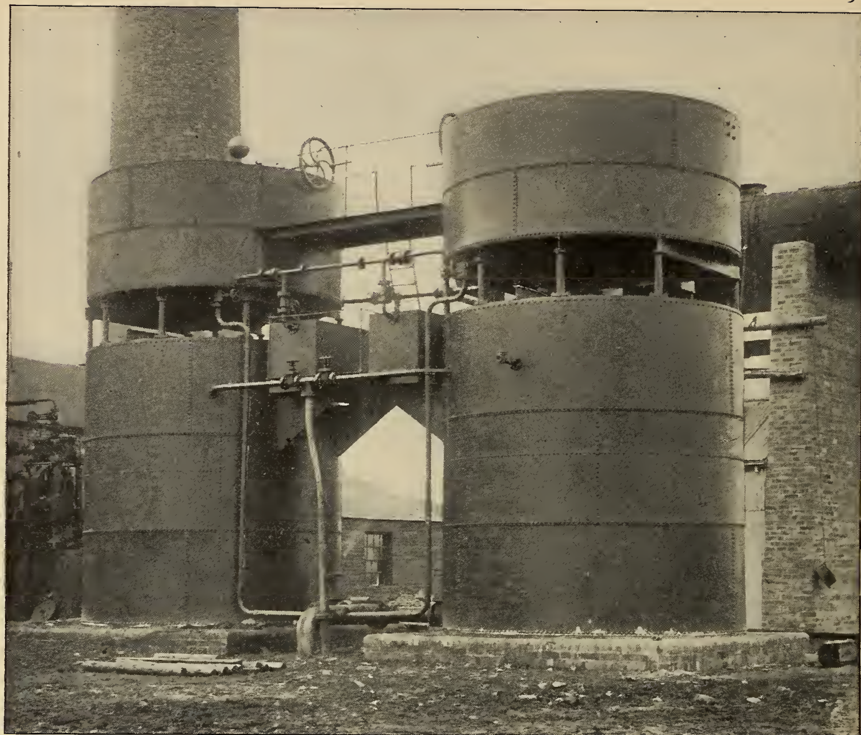


A CHEVALET HEATER AT THE WORKS OF THE CHELSEA ELECTRICITY SUPPLY COMPANY

regulated that two portions into which the flow from the main supply pipe is divided, may always preserve the same ratio, whatever be the rate of flow itself. One portion enters the softening tower direct, and the other is mingled with it after saturation in the lime mixing apparatus.

Soda, when required for the treatment of permanent hardness, is also subjected to automatic control in the following manner:—A defined proportion of the main supply enters a pipe having two branches, one leading to a dissolving vessel containing soda crystals, and the other connected with the soda solution tank. The latter is in communication with the soda supply vessel, which contains a hydrometer. This instrument is arranged so as to rise and fall in accordance with the specific gravity of the solution, and its motion is caused, by means of suitable mechanical contrivances, to regulate the proportion in which water flows through the branched pipes. Thus, if the solution begins to acquire more than its proper quotum of soda, the passage of water through the dissolving vessel is cut off or diminished and water enters the soda solution tank until the standard strength is again restored.

The apparatus illustrated shows a machine capable of softening about 5000 gallons an hour. When larger quantities are required, it is only necessary to add to the number of clarifying towers, and in this way the output may be



THE HOWATSON WATER SOFTENING APPARATUS, MADE BY MESSRS. THWAITES BROS., BRADFORD

increased up to 500,000 or more gallons daily.

In the clarifying vessels various internal fittings are used, but perhaps the best form is that in which the interior of the tower is occupied by a series of inverted cones, or, if the towers are rectangular, by inverted pyramids. In either case the funnels are perforated with even rows of holes, so that the sediment slides down between them. To the apex of each funnel is attached a tubular neck, the lower end of each extending into the upper portion of the neck next below, and the lowest neck ends below the level of the water inlet. The effect of this arrangement is that a central column of perfectly quiescent water is formed, through which the precipitate from each funnel falls freely into a receptacle in the lower portion of the tower, and may be drawn off in a thick cream by the mud cock, which is placed within the outer shell of the tower, and is thus protected from the weather.

During its passage through the clarifying tower the water ascends gradually and under conditions favourable to the deposition of the suspended particles. Finally, the water passes through a filter bed of wood-wool and issues clear and soft from the top of the apparatus. A separate filtering plant is not usually considered necessary. The flow of water through the entire apparatus is governed by a throttle valve, actuated by a ball floating in the storage tank or supply cistern.

The Stanhope softener and heater for feed water combines the process of softening with that of heating the water by exhaust steam. Of course, the act of heating is, in itself, of some assistance, but is not relied upon in this apparatus, as chemical softening is resorted to in addition. The body of the heater is used as a clarifying vessel, and the us-

ual methods are adopted for the automatic mixing and supply of the necessary reagents.

The Chevalet heater and detartariser is an apparatus presenting some novel features which are worthy of examination. The action is based on the fact that, by boiling water for a sufficient time, the unstable bicarbonates are decomposed, and insoluble carbonates are precipitated. Under ordinary circumstances softening by heat is a somewhat expensive process, but this objection does not affect the case of feed-water heaters, especially when exhaust steam is the source of heat. Sulphate of lime, or permanent hardness, is treated by the addition of carbonate of soda, the employment of caustic soda being considered to be unnecessary in this apparatus. Soda solution is injected into the hot water by a small reagent pump attached to the main pump, with which it works in unison. Therefore, the supply of soda solution always bears a definite relation to the main supply, and the strength of the solution is proportioned to the character of the water.

The apparatus consists of a number of trays or sections, which are seen in the sectional elevation on page 468. Each tray, when working, is half full of water, which flows downwards from the top through the various sections and finally into the hot water receiver at the base. Exhaust steam enters at the bottom, above the water level of the receiver, and passes upwards through the water by the tubular openings *J*. Over each of these an inverted cup *K* compels the steam to pass through the water, which is heated to the boiling point by condensation of the steam, and any surplus steam is discharged by the pipe at the top of the apparatus.

A SET OF TORRENT FILTERS, MADE BY THE PULSOMETER ENGINEERING CO., LTD., LONDON

Lime salts contained in the water are deposited as compact scale in the various sections, but never become hard, and consequently are readily removed.

For the purpose of cleaning, the sections may be lifted down and the deposit scraped off. Owing to its simplicity of construction, it is said that the apparatus may be thoroughly cleansed within four or five hours. All grease

A GENERAL VIEW OF THE MILTON WATER WORKS, EQUIPPED WITH ARCHBUTT-DEELEY WATER SOFTENING APPARATUS, MADE BY MESSRS. MATHER & PLATT, LTD.

WATER SOFTENING PLANT FOR THE MIDLAND RAILWAY, AT DERBY, INSTALLED BY MESSRS. MATHER & PLATT, LTD., MANCHESTER, ENGLAND

present in the exhaust steam is absorbed by the lime deposit, and, therefore, none can pass into the heated and softened feed-water yielded by the apparatus.

In the Andrew Howatson water softener, the velocity of flow is reduced so that the water is almost quiescent when under treatment. Thus, both chemical action and the precipitation of particles are facilitated. For use with certain classes of water, rows of plates, placed at an angle, are fixed in the settling tank, and above them is placed a bed of shavings for the purpose of distributing the water currents.

The illustration on page 470 shows a double apparatus capable of treating about 8000 gallons of water per hour. Each tower is 12 feet in diameter and about 25 feet in height, whilst the ground space occupied measures about 30 feet by 15 feet. In the upper reservoirs, the chemicals are mixed and prepared, being supplied with water from a pipe which also supplies the square tanks occupying an intermediate position. The latter are divided into two large compartments, each fitted with ball valves, one acting as a supply-tank for hard water, whilst the other serves to regulate the quantity of reagent received through a floating pipe from the upper reservoirs. Between the two large compartments is a smaller receptacle, in which the water and reagents mix, the relative quantities being automatically regulated by nozzles of correctly proportional sizes.

On entering the lower reservoirs, the mixture traverses a wide passage, extending from top to bottom, in which chemical reaction takes place. Leaving this passage, the water rises, passing in its ascent through a layer of filtering material, in which it leaves any particles which have not been deposited. Above the filter bed is a space or reservoir for clarified soft water, which is drawn off by a pipe, as shown in the illustration.

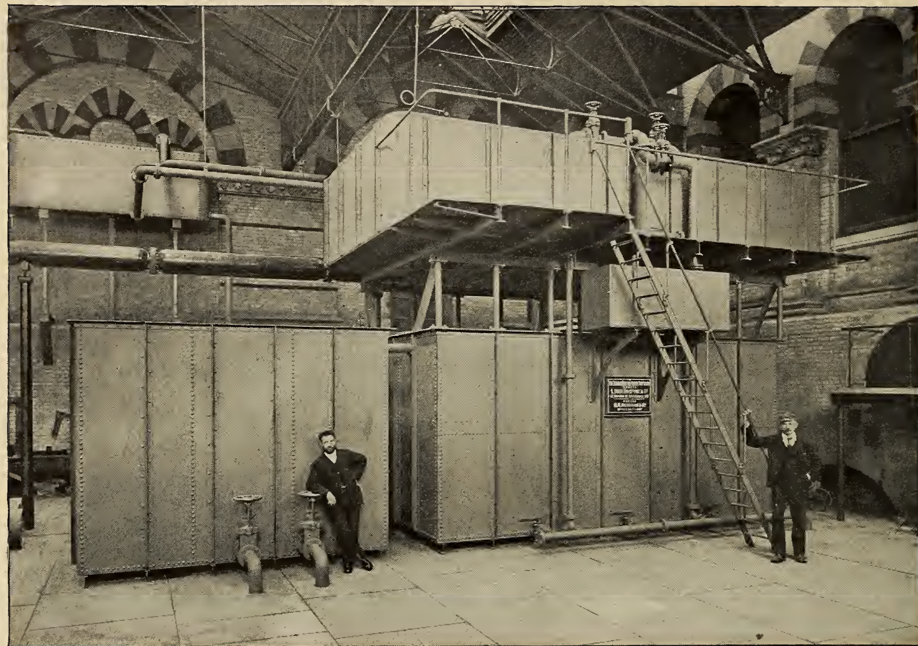
When the water rises to a certain distance above the outlet, the supply of both water and reagent is cut off by the action of the ball valves before mentioned, so that there is no overflow causing waste. The machine is entirely automatic whilst the upper reservoir is duly charged, except that it is necessary for the mixture in the latter to be agitated occasionally by means of a stirrer provided with the apparatus. Drain cocks are provided for both reservoirs, so that precipitated matter may be washed away from time to time, and the apparatus is under the general control of a master-cock.

When desirable, the Howatson system of filtration may be applied for the further clarification of water after the softening process. The filters are made in two forms, one working under pressure, whilst the other is open to ordinary atmospheric pressure. A further distinction is created by variation of the material constituting the filtering medium, which, when the water is intended for industrial purposes, consists of a bed of crushed silex, to which a bed of "polarite" is added if the water is required for domestic use.

Cleansing is effected by the admission of a reverse current of water, and in some cases a circular rake, driven by hand gear, is used for the purpose of assisting the process, by breaking up the layer of foreign matter which forms on top of the filter bed.

Water softening processes, as conducted in well-regulated forms of apparatus, are capable of removing from 90 to 95 per cent. of the particles liberated, and under such conditions the water is entirely suitable for all ordinary purposes. It sometimes happens, however, that absolute clearness is essential, and the employment of filters, to some of which reference has already been made, then becomes advisable.

The Torrent is a well-known type of filter recommended by the makers, the Pulsometer Engineering Company, Ltd., for use with their own or other water softening apparatus. The containing vessel in this filter is made of wrought or cast iron, of either cylindrical or rectangular shape, and is furnished with a layer of filtering material placed on a grating, beneath which is an air distributing apparatus. Water enters at the top and leaves at the bottom, freed from suspended particles.



A CARROD WATER SOFTENER PLANT, INSTALLED FOR THE LONDON COUNTY COUNCIL, BY MESSRS. W. R. RENSHAW & CO., STOKE-ON-TRENT

As such intercepted matter consists largely of insoluble earthy salts, it is, of course, necessary that simple means should be provided for frequent and rapid cleansing. This is performed by the simultaneous admission of a reversed current of water and a quantity of high-pressure air supplied by a steam blower attached to the filter. Thus the whole of the filtering material and the impurities are violently agitated and the particles of foreign matter are washed away through a mud-hole.

The water softening apparatus erected by the same makers is constructed in varying forms to suit individual requirements. The tanks may be circular or square, and in some cases existing tanks may be utilised.

The Tyacke water softener consists of a cylindrical vessel which is surmounted by two square tanks. The upper receptacle contains the chemical reagents, which are mixed in proportions determined by analysis. Hard water is conveyed into the second and smaller tank, where it is mixed with the reagent; the mixture is then conveyed to a tube in the vertical vessel which contains a spiral coil. The object of this is to insure thorough mixture and to aid the deposition of precipitates. Water and deposit gradually work their way downwards, the latter falling to the conical bottom of the cylinder, where it is drawn off through a suitable valve. The water then rises gradually outside the tube, and after passing through a filter is drawn off for use.

The Porter-Clark water softener cannot boast of an exclusive claim to this title, as most forms of softening apparatus before the public are made in accordance with the Porter-Clark process. The softener is made in various forms, one of the smaller being adapted for working under pressure from the mains without the aid of other motive force. This type is capable of treating about 350 gallons a day. Another form softens 1200 gallons an hour, and in this, lime-water is pumped from an adjoining vessel to the softening cylinder. The water, before use, is passed through a filter.

A special form of purifier, used with-

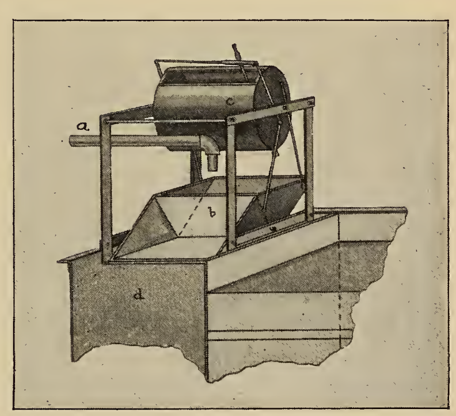
out motive power, consists of two upper tanks, containing reagents, and a vertical rectangular softening tank. Although effective, the apparatus in this form entails considerable attention and labour. A more recent arrangement, employing power, includes tanks for reagent, for mixing, and for filtering, the latter process being conducted by means of hanging filter cloths. After filtration, the water is drawn away by a steam-pump.

Another apparatus, extensively used on the Continent prior to its introduction into Great Britain, is the Bruun water softener, in which lime-milk,—a mechanical mixture of slaked lime and water,—is used. One of the chief disadvantages connected with the use of a mixture of lime and water is to be found in variation of strength, which, however, does not occur in practice when a saturated solution is used. To overcome this objection in the Bruun softener, an oscillating tank is provided, whose function it is to keep a constant quantity of lime suspended in the water.

This tank, and the apparatus with which it is connected, are shown in the diagram on this page, in which *a* is the pipe through which the water to be heated is led into one of the chambers of the oscillating receiver *b*. When this chamber is filled, the centre of gravity is changed and the receiver tips over, pouring its contents into the mixing tank *d*, at the same time bringing the other chamber of the receiver below the orifice of the pipe *a*.

To the receiver is fixed a system of levers, which, at every oscillation, cause the reagent tank *c* to oscillate also, and, in addition, the levers actuate a valve, fixed to the bottom of the reagent tank, through which a certain proportion of the chemicals are mixed with the water. From the tank *d* the water passes through a pipe extending to the bottom of the clarification cylinder. Impurities are deposited at the lower portion, and pure water, ascending through the filter, is drawn off for use. Chemicals are delivered to the top of the apparatus by means of a pump, which is not seen in the illustration, being situated behind the cylinders.

The Archbutt-Deeley apparatus involves a process which, in its mechanical operation, differs from those adopted in other forms of water softening appliances. Two tanks are provided, placed side by side, each with similar internal fittings, so that they may be alternately used for softening and storage. Hard water is admitted to either tank by a supply pipe from a pump or main. The necessary chemical reagents, in proportions which are varied in accordance with analytical results, are boiled in an auxiliary tank by means of live steam, and the solutions are completely diffused throughout the water by aid of a steam injector used in connection with a sys-



A DETAIL OF THE BRUUN WATER SOFTENER

tem of circulating pipes. Deposition then takes place, and the clarified liquid is drawn off into the second tank, the precipitate being allowed to remain on the bottom of the first receptacle, where perforated pipes are fitted. Through these, in subsequent operations, air is blown, thus disturbing the old precipitate, which comes into contact with the newly-formed particles suspended in the water. In this manner the process of clarification is materially accelerated and occupies about an hour.

As the clarified water is being drawn off, it is re-carbonated by carbonic acid, just sufficient to convert any floating particle of insoluble carbonates into soluble bicarbonates. This object is effected by drawing off the water through a floating hinged pipe into

the upper end of which is introduced carbonic acid, generated from a coke stove.

The illustration on page 472 gives a general view of the Milton waterworks, at which an extensive plant on the Archbutt-Deeley system is in use. This installation is intended for the treatment of 45,000 gallons of water per hour, which is equal to an output of over a million gallons in 24 hours. In its original condition the water has from 21 to 23 degrees of hardness, which during softening is reduced to about 8 degrees. Besides earthy salts, this particular water is impregnated with iron to an undesirable degree. The presence of so small a proportion as a fifth of a grain per gallon is sufficient to impart a perceptible taste to water. Whatever may be the therapeutic value of iron, it is no part of the duty imposed on a public waterworks to enter into competition with the medical profession, especially when consumers do not require or may object to the gratuitous administration of tonics. Further, the presence of iron in water renders it unfit for dyeing, cleansing and other industrial operations. Existing as bicarbonate, iron is readily precipitated by means of lime, and, if exposed to the action of air, the bicarbonate rapidly loses carbonic acid, at the same time absorbing oxygen, by which it is converted into red oxide of iron, or rust. The Archbutt-Deeley process, as already mentioned, involves the thorough aëration of the water under treatment, and is, therefore, extremely well adapted for the removal of iron.

At Milton the total cost of treatment is estimated by the engineers, including interest and outlay, depreciation, steam, labour and chemicals, at less than three farthings per thousand gallons, and they further state that "without the softening apparatus, the water would be unfit for town supply, but that, after the process, the whole of the consumers are delighted with it."

The illustration on page 472 shows a plant, capable of softening 30,000 gallons per hour, which has been in operation for some years at the locomotive works of the Midland Railway Company, at Derby. The apparatus there consists of three tanks, each 23 feet, 6 inches square and 10 feet high, and approximately covers an area of 85 feet by 25 feet.

The Carrod water softener, as illustrated on page 474, is a machine in use by the London County Council for softening boiler feed water at their Abbey Mills pumping station, at West Ham. This installation is capable of treating 100,000 gallons daily, and occupies a space of 18 feet by 10 feet by 18 feet, 6 inches high. Although the process is carried on without interruption, the preparation of reagents is not continuous in the sense of the word as used in connection with previously described machines. The reagents are here mixed in duplicate cisterns, used alternatively, the mixture being made in one, whilst the other is in use, so that the process need never become intermittent. Water for treatment is admitted to the clarification tank from a mixing trough, which may be placed in communication with either mixing cistern, and the proper proportion of reagent passes in at the same time, the quantity of each being regulated by nozzles of appropriate sizes. The flow is maintained at a constant velocity by the passage of the feed in each instance through regulating tanks fitted with ball valves, so that the same head of water may be insured at all times.

On emerging from the mixing trough into the clarifying tank, the water is conveyed, by means of a pipe, to the bottom, and then passes upwards. By the time it reaches the outlet, the water is sufficiently clear for immediate use, and may be drawn away direct or allowed to flow into a storage tank. The apparatus is automatic in action; the opening and closing of one cock starts or stops the machine, and ample means are provided for cleansing and washing out the apparatus.

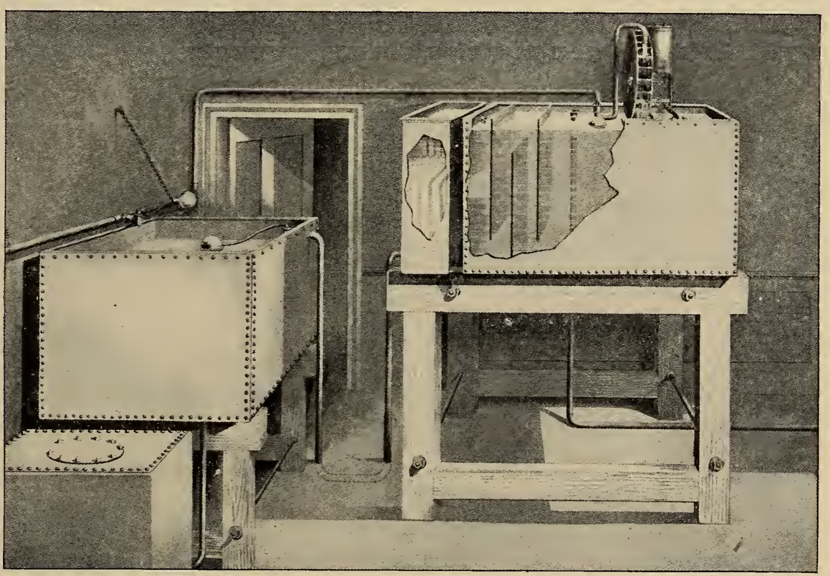
One of the earlier water softening processes introduced into Great Britain was that known as Maignen's. Whether intended for private houses, industrial undertakings, or public service, the

processes adopted are practically identical, and involve the employment, by the user, of reagents prepared in the orm of a powder by the patentees, in proportions adapted to suit the quality of different waters. This powder consists of lime, carbonate of soda, or caustic soda and alum. The latter, on being neutralised by alkali, forms alumina, which materially aids in the clarification of turbid waters. There is no doubt that for householders the use of the powder saves considerable trouble, and perhaps makes practicable the adoption of water softening apparatus which might otherwise be rejected on the score of trouble and extra attention necessary. But large consumers may very reasonably prefer to buy the reagents in the ordinary manner.

In the Maignen apparatus, the hard water delivered falls upon a water-wheel, thus communicating movement to gearing placed inside a receptacle containing the softening powder which is forced out of a slot. The aperture of this slot can be regulated in accordance with the resultant degree of hardness desired, and the softening reagent falls into a conical funnel fixed in the tank, where it meets the water from the wheel.

Descending to the apex of the cone the water and powder are well mixed, and issue into the body of the tank, in which chemical action takes place. An adjacent tank, fitted with a cone having a wider mouth at the apex, is connected with the other by a pipe, and there clarification takes place, the water descending outside the cone and ascending its interior. At the upper part a pipe leads the water into a filter tank, in which are a series of wood frames covered with asbestos cloth. The softened water then passes into a storage tank.

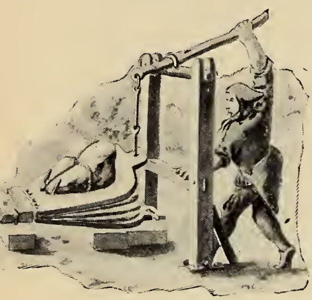
Although there are other types of water softening apparatus which might be described if space permitted, enough has been said to show that considerable ingenuity and engineering skill have been brought to bear on a question whose importance is still insufficiently recognised by the general public.



MAIGNEN'S WATER-SOFTENING APPARATUS. MADE BY MAIGNEN'S FILTRE RAPIDE AND ANTICALCAIRE CO., LTD., LONDON

THE EARLY USE OF ROLLS IN THE MANUFACTURE OF METALS

By W. F. Durfee, C. E.



THE opinion seems to be pretty general among British and American metallurgists that the art of rolling metal originated in Great Britain, and that the world is indebted to the Englishman, Henry Cort, for the invention of grooved rolls for rolling iron. This view, like many popular opinions relative to historical matters, is entirely erroneous, and it is proposed to call attention here to some of the visible steps by which the art of rolling metals progressed from its unrecorded origin to the alleged invention of Henry Cort in 1783.

The earliest description of a rolling-mill is that of Solomon De Caus. In his work, "Les Raisons des Forces Movantes," published in 1615, he gives an illustration, reproduced in Fig. 1, of a mill for rolling sheets of lead and tin, for use in making the pipes of organs. He calls his mill "a tool by which lead and tin are powerfully squeezed smooth and of an even thickness," and describes it as follows:—

"After the lead and tin are cast, we have a tool for smoothing it, made as we see in the figure, in which there are two rolls of iron or copper, marked *A B*, truly round and smooth, as are also both their bearings and axles. To the lower axle is attached a cross, having strong arms, for turning the roll, and between the rolls we put the piece of lead that we wish to make smooth, and, turning the cross, the lead passes between the rolls, and they will make it very smooth and bright. After that is done, to give such thickness to the lead as we may desire, the two screws marked *C D* are turned. These press a piece of copper against which the axis of the roll at the top turns. The arrangement can be much better understood by the detail marked *E*, and exactly as we treat the lead we shall treat also the tin."

The next inventor of rolls, in chronological order, was Signor Giovani Branca, who, in the title-page of a book written by him, describes himself as a "citizen of Rome, engineer and architect." Signor Branca's book was published at Rome in 1629. Fig. 2, reproduced from this work, reveals a very curiously contrived rolling-mill, as to which it is hardly necessary to say that it never could have done any useful work by using, as a motive force, the smoke escaping from the chimney of a left-handed blacksmith's forge fire. But the picture, when taken in connection with Signor Branca's description, suffices to show that he had a clear idea of the theory of shaping metals by rolls.

It is evident that he understood that considerable power would be necessary. This is shown by the gearing introduced to convert the supposed rapid revolution of the flutter wheel at the chimney into a slow and powerful movement of the rolls. As near as can be estimated from the proportions of the gears and pinions in the plate, if the flutter wheel made four hundred revolutions per minute, the rolls would make about six in the same time.

Signor Branca's illustration, considered as a mechanical drawing, is suggestive of King David's description of the structure of man, for it "is fearfully and wonderfully made." Just how the

hammer of the blacksmith finds its way behind the framework supporting the chimney, is like the famous conundrum of Lord Dundreary:—"something that no feller can find out." In describing his invention Signor Branca says:—

"In the figure is shown a method of forging masses of gold, silver or other metals, and by which even medals and coins may be appropriately impressed. In the foreground we see an artisan working at the anvil *T*, with a hammer.

"The furnace *M*, which is blown by bellows, is placed under a chimney, *L K H G*. When the furnace is put in operation the air in the chimney is highly heated, and, together with the smoke that is produced, causes the fly-wheel *I* to turn around. This sets in motion the pinions *N P R* which, in turn, gear into the wheels *O Q F*, and, finally, the roll *A*, which is attached to the wheels *F* and *D*, is made to revolve. The workman *V* causes the unwrought metal, which he desires to have worked, to pass between the rolls, or to be pressed forcibly into the dies *B C* which have been engraved with the wished for pattern upon the rolls. All of which is made clear by the figure."

An especially interesting detail, from a historical point of view, of this scheme of Signor Branca is the gearing together of the top and bottom rolls by the gears at *D*, secured to the necks of the rolls. This is exactly the construction employed in some of the earlier "puddle rolls," and the writer has seen it in practical use as late as 1870, in an old mill now dismantled.

The next rolling-mill, in point of time, is that described by Vittoria Zonca in his work, "Nova Theatro di Machine et Edificii," published in 1656. This author claims to have been an "architect of the magnificent City of Padua," and the rolling-mill which he presents to us is entitled "rolls for making grooved lead rods for glass windows," his explanation of them being as follows:—

"There is no doubt that the machine about to be described is a species of wheel and axle, embodying the principle of the lever; for the small crank or handle, by which the rolls are turned, has a more or less powerful movement in proportion to the diameter of the circle in which it travels, and whenever its length is properly adjusted to the resistance to be overcome, little strength will be required; thus, by care and ingenuity, the rolls will be found to turn easily. I will also say, relative to

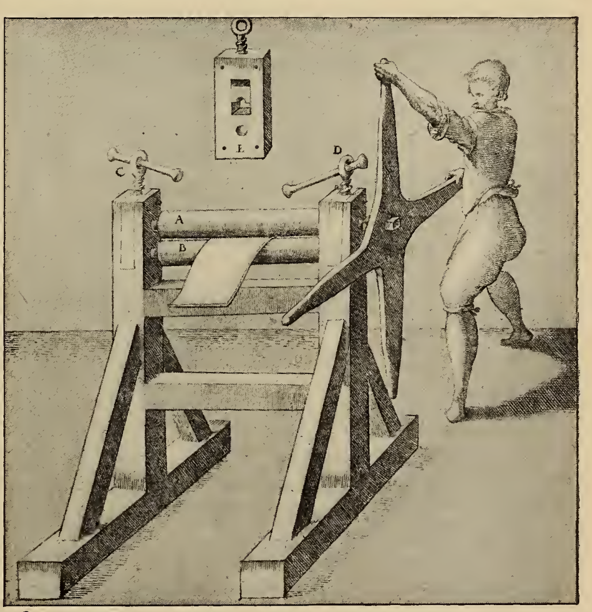


FIG. 1.—A MILL FOR ROLLING LEAD AND TIN SHEETS FOR MAKING ORGAN PIPES, 1615

the small power required for this machine in comparison with others in which the motions are in various and contrary directions, that other machines have a number of wheels acting together in a secret manner, as in certain kinds of clock-work; or as in some ornamental structures in which small figures move up and down in such a way as to amaze and amuse the be-

holder, the cause of their motion being concealed and only the result seen.

"In the present machine the working parts are inclosed, and secured by iron bolts, and also fastened at the base,

FIG. 2.—BRANCA'S METAL-ROLLING MACHINE, 1629

and are operated by a crank or handle. The grooved lead rod is forced out by something invisible within the machine, and the operation is so surprising that it almost suffices to cause the spectator to burst with amazement.

"To the end that the operation of this machine be better known, I have prepared a plate containing three figures, and hope thereby to make its construction clearly understood. The machine is very carefully made, and in this respect it is similar to many beautiful machines I have recently seen; not only the rolls which groove the lead, but their axles, are made of steel, in order that they may easily turn when required.

"The screws in the upper part of the machine are well designed to adjust the rolls with reference to the crank by which they are turned in their inclosing frame. The rolls are shown in section, marked 1 in Fig. 4, and the lever action of the crank is seen at 2 in Fig. 4. The back part of the frame of the machine, shown in diagram 1, has seven round holes, like those in the front part of the frame. The two middle holes are for the passage of the necks, or axes, of the rolls, and are lined with bushings of brass, in which the steel necks of the rolls turn. Brass is used because it is strong and free from imperfections.

"The small 'guide' in the centre is made of steel, so as to better preserve the form of the lead which this guide assists the rolls in shaping. The two other guides are made of tough walnut wood. Four of the other holes seen are for the passage of screw-bolts, which hold the parts of the machine together. When the machine is closed up it is secured by a single bolt (fastened inside at one end) to something solid and immovable, in order that it can be properly operated. Furthermore, in the inside of the upper part of the frame grooves are cut, in which are bolts, having at their lower ends bearings which press upon the necks of the up-

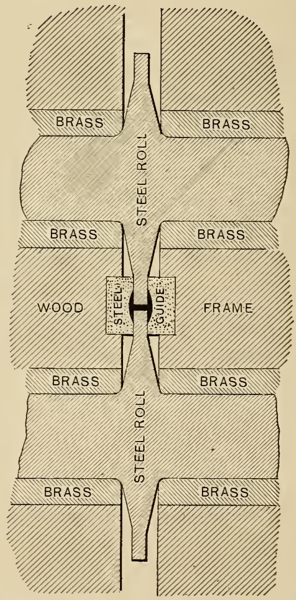


FIG. 3.—SUPPOSED VERTICAL SECTION OF ZONCA'S ROLLING MILL

per roll and prevent the rolls from separating. This is the way the machine is constructed, and when it is put together the lead can be run out in the form of rods having grooves on opposite sides.

"I will say, finally, in short, the machine consists of a closed case like diagram 2, Fig. 4, in which we observe the crank of the rolls; and in diagram 3 we see the machine being operated by the master workman."

Referring to Fig. 4, Zonca supplies the following references:—

"*A*, The rolls and their necks, made of strong steel; *B*, bolt which is placed in the groove in diagram 1; *B'*, attachment to the bolt *B*, having a milled head *M*, for adjusting the roll; *C C C C*, holes for screw bolts; *D*, square groove for containing the bolt *D*, for securing the machine upon a bench, as in diagram 3, Fig. 3; *E*, bearings bushed with brass for the necks of the rolls; *F*, small discharge guide through which the grooved lead issues; *G*, opening through which scrap lead is removed; *H*, crank by which the rolls are turned."

In this machine the rolls were probably without grooves, the peculiar double-channel or *I*-beam section of the lead rod being produced by the action of the rolls in connection with the central steel guide, which assisted "the rolls in shaping" the lead. The guide was, doubtless, made somewhat flaring at its ends to facilitate the entrance of the plain rod of lead and the egress of the grooved rod, and also to diminish friction.

In Fig. 3 the writer presents what is supposed to have been the section made by a vertical plane containing the axes of the rolls, the black space between the rolls and guide showing a cross-section of the lead rod.

The transactions of the Académié des Sciences for 1728 contain an account of a very remarkable machine "coming from England and described by M. Fayolles, engineer." This machine was "for rolling sheets of lead," and it is said to have been "similar to that in use at Homburg; and by it the lead was passed and repassed between two rolls without loss of time; and there is a simple and ingenious regulator by which the exact thickness of the sheet can be determined."

The rolls of this machine were of iron, 5 feet in length and 12 inches in

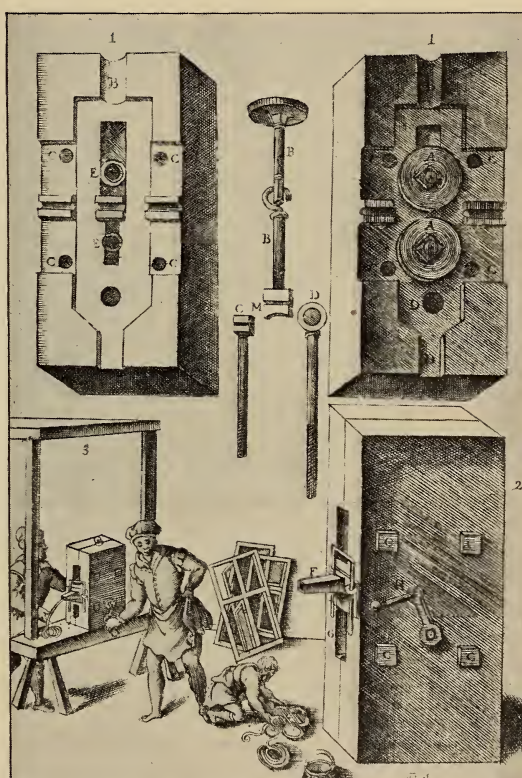


FIG. 4.—ZONCA'S METAL-ROLLING MACHINE, 1656

diameter. On the front and back of the rolls were "roller tables," 24 feet long, provided with a multitude of rollers for supporting the sheet lead, as it "passed and repassed" through the mill; these "table rollers" were 4 inches in diameter and placed 12 inches from centre to centre. There was a "worm wheel and screw" adjustment

for the top roll, said roll being suspended by a weighted lever.

This mill was what is now known as a "reversing mill," its reversal being accomplished by a lever operating a clutch in connection with suitable gearing, some of the wheels of which were said to have been made of copper. All the leading mechanical ideas in this mill anticipated perfectly those of some modern reversing mills used in the manufacture of steel plates, and it is an admirable illustration of the mechanical skill and inventive ability of its time. But what makes it of special interest, historically, is an engraving of a pair of grooved rolls, 5 feet in length and 16 inches in diameter, which could be put in the place of the plain rolls, and the mill could then be employed for rolling lead pipe upon a mandrel.

These rolls contained seven semicircular grooves of varying sizes, the largest being 4 inches, and the smallest, 2 inches in diameter. The lead ingot was cast hollow, but much larger in external diameter, and proportionally shorter, than the intended pipe. When cooled, it was put upon a long mandrel and passed forward and backward through the several grooves in the rolls until the pipe was of a proper external diameter; then the mandrel was withdrawn.

Notwithstanding that this machine is said to have come from Great Britain, there is no evidence in the British patent records that such a mill was in use in that country at, or before, the time it was brought to the attention of the Académié des Sciences in 1728; but it is evident that the "art and mysterie," (to use a wording common in old patents) of extending metal into plates or sheets by means of plain rolls, and of forming round bars by the use of grooved rolls, was clearly embodied in it, as set forth and described by Fayolles, and this mill must also be counted among the early steps in the progress of the art of "cold-rolling" metal towards its present important position.

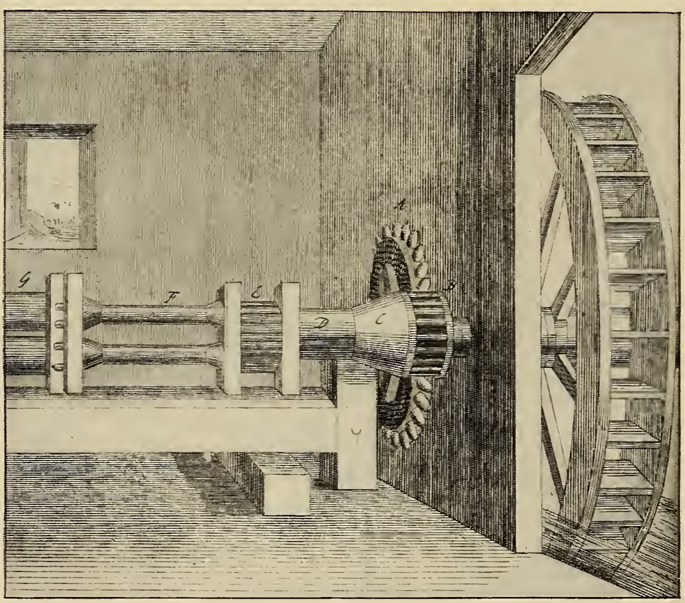


FIG. 5.—A SWEDISH PLATE MILL OF 1734

In a British patent granted to John Payne (Nov. 21, 1728, No. 505), he says, in the specifications, that hammered bars are made "to pass between two large metal rowlers (which have

proper notches or furrows upon their surfass) into such shapes and forms as shall be required." If the words quoted do not describe grooved rolls, it is difficult to say what they do describe.

In Emanuel Swedenborg's work, "De Ferro," published in 1734, there is an illustration of a "slitting-mill." In this mill the heated bar was first passed between a pair of plain rolls to reduce it to an even thickness, and then through the "slitters" which "slit" it into small rods. Such mills were in use in Sweden at that time, and Swedenborg speaks of their being employed in England, and near Liége, and in Germany.

In his treatise on copper and brass, published in the same year, an account is given of a plate or sheet mill under the title, "The Method of Coining Money." Swedenborg says:—

"In the vicinity of Aswedstadium various denominations of money, large and small, are coined. The weight is adjusted by weighing in scales until each blank is neither heavier nor lighter than intended; but I cannot open the door and reveal the tools, machines, and mechanical appliances used, and the subjoined delineation must suffice.

"Fig. 5 represents the machine by which heavy plates are usually compressed to a thickness proper for small coin. At *G* are the rolls between which the copper is squeezed into thin plates. The construction of this machine remains to be described, but it is common, and, consequently, known."

The picture gives a rather foggy and indistinct notion of the actual construction, and it is evident that the distinguished author did not care to go into details too minutely.

Swedenborg has also something to say about iron being "extended between rolls" at Liége, in England, and in Sweden, although he does not speak positively of the rolls being grooved. He tells us that the iron is heated at Liége by "mineral coal," and in reference to rolling-mills in England he says:—

"In England there are also more machines by which a second quality of iron is drawn out into rods and hoops, cut suitably to tie up in separate bundles. . . . Iron is also made into thin plates there, a part of which are covered with tin; but in making this thin iron it is said that one-twentieth part of it is wasted, and furthermore, the iron may not be of good quality."

On December 23, 1752, a report was made to the Académié des Sciences by a commission appointed to examine a mill for rolling iron bars of various cross sections, which had recently been erected at Essonne. A portion of this report was published in 1757 in the "Encyclopédié ou Dictionnaire Universel des Arts et des Sciences," and from this the following quotation has been taken:—

This rolling-mill is "composed of two rolls of iron *C D* (Fig. 7), the upper one *C* having a circumferential groove for impressing upon the flat bar *A B* the mouldings desired. The two rolls of this mill are driven by two water-wheels. The lower roll *D* is driven directly by a shaft with which the square end at *F* is connected by means of a coupling box *G*. The other roll is driven by reversing gear, which turns the roll above *G* in the contrary way. The two rolls being in motion, we introduce the bar of red-hot iron on which we wish to form mouldings, so as to catch between the two rolls, and be drawn in by their motion, and the bar is elongated, and moulded by a single operation, over its entire length, in a very short time.

"In order to prevent the bar of iron operated upon from wrapping around the rolls, a workman seizes it as soon as it appears on the opposite side of the rolls and holds on to it until it leaves them."

From a very interesting and historically important letter which Professor Richard Åkerman wrote to Mr. James M. Swank, of the American Iron and Steel Association (relative to the early history of the rolling-mill), and which was printed in Mr. Swank's comprehensive and valuable work, entitled "History of Iron in All Ages," the writer extracts the following notice of

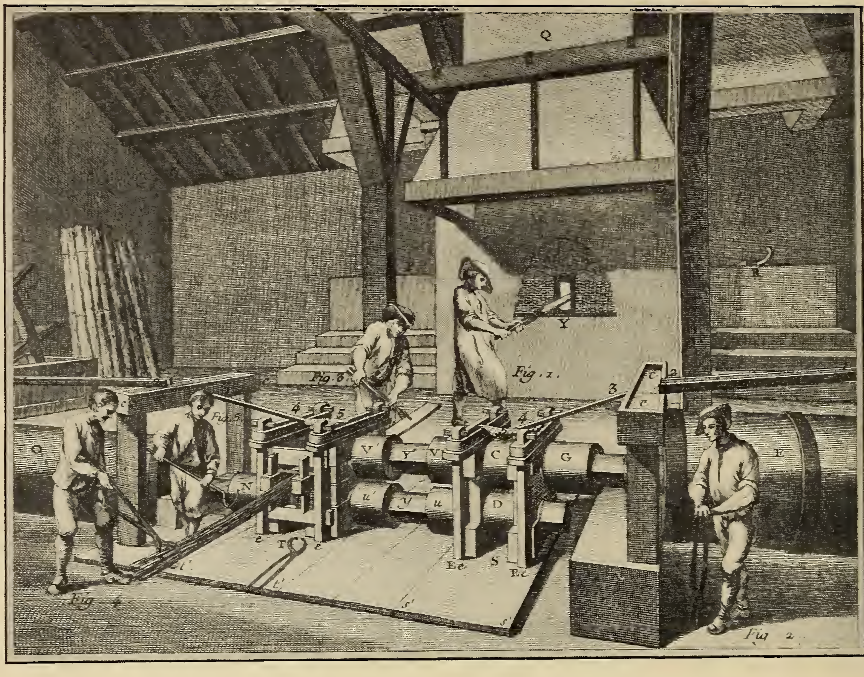


FIG. 6.—A FRENCH SLITTING MILL OF 1757

Christopher Polhem, who was one of the ablest mechanicians of the time in which he lived (1661-1751). Professor Åkerman says:—

"'Christopher Polhem, in his 'Patriotiska Testamente,' which was printed in 1761, ten years after his death when he was ninety years old, speaks about rolling mills as such, both for plates and bar-iron. He says, in Chapter XIV:—

"'Much time and labour can be saved by good rolling-mills, because a rolling-mill can produce 10 to 20 times and still more bars in the same time that is wanted to tilt only one bar with the hammer. Thus very thin bar-iron can be made which is useful for hoops and mountings of several kinds. Steel also can be rolled out for knife blades, etc., which easily can be finished by the blacksmith. The rolls can be so made that the knife steel becomes broad and thin on both sides, or gets the same shape as blades of common swords, and these can be cut lengthwise in two parts, thus giving suitable material for knives, etc. Rolls also can be made for producing quadrangular, round, and half-round bars, not only for iron, but also for steel, as for all kinds of files, which easily can be finished by the blacksmith.'

"In the next chapter Polhem describes the manner of making wrought-iron rolls, covered with steel. Further on, in the same chapter, he speaks of rolls for rolling sheets:—'As such rolls commonly have a length of three-quarters, it follows that their diameter must be rather large; but, as thick rolls in comparison with slender ones have only a small effect in stretching, broad sheets cannot be rolled. If not, two slender wrought-iron rolls are put between the two thick cast iron rolls, which prevent the slender rolls from yielding. Such rolls I have put up at Stjernsund after having tried their effect by experiments on a small scale.' After mentioning economical difficulties, in consequence of which he was obliged to leave unused both this and other expensive machines, he concludes with the following words:—' Yet I will-

ingly grant to others, who perhaps will live during more happy times, what I have not got opportunity to use for myself.'

"Polhem says nothing about the time when he put up the said rolling-mill; but, if you remember that he was born in 1661 and died in 1751, it seems probable that it must have been during the first decades of the eighteenth century. Christopher Polhem was the greatest mechanical genius Sweden has ever produced, but whether he was the very first inventor of rolling-mills it is impossible for me to say. At any rate, he ought to be mentioned among the inventors of rolling-mills. In fact, Polhem must be said to be the real inventor of what you call the Lauth rolling-mill. The only difference is that Polhem used four rolls above one another, two small ones between two large ones.

"Gabriel Polhem, a son of Christopher Polhem, in the transactions of the Royal Swedish Academy of Sciences for 1740, gives a description of a rolling-mill, 'the invention of my father,' which he (Gabriel Polhem) put up at the mint in Cassel, Germany. He says that the officers of the mint did not believe that a rolling-mill could be of any use for the mint; but he was, in 1733, ordered by King Frederick to put it up, and it proved most useful for getting more uniform thickness and weight of the coins. From this and other expressions in the description, it is quite clear that this rolling-mill was the very first put up at any mint; but not long afterwards a rolling-mill also was put up at the Swedish mint."

This last mill mentioned by Professor Åkerman was, doubtless, that so briefly described and rudely illustrated by Swedenborg, whose account of it has been already given.

In 1759 an English patent was granted to Thomas Blockley for "polishing and rolling metals." In his specifications Blockley says:—"Let two rolls for rolling iron be prepared, turned in such different forms as occasion may require. And the same are to be rolled right-hand and left, two or more together."

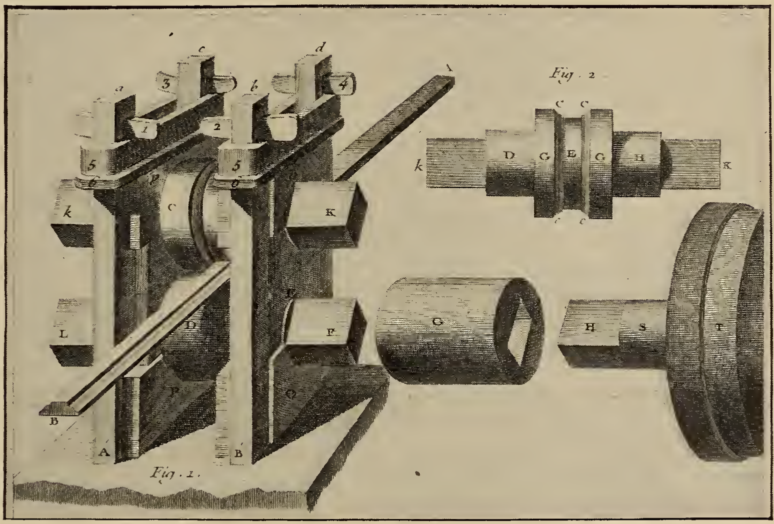


FIG. 7.—A FRENCH ROLLING MILL WITH GROOVED ROLL, 1752

This, as the writer understands it, amounts to nothing more or less than turning up a pair of grooved rolls as occasion required. Blockley's patent solicitor evidently understood the art of drawing a specification that would include every form of roll that could be turned.

In 1772 Mark Homer received a Brit-

ish patent, in which he claims:—"Iron, copper, or a mixture of copper and brass, is coated with fine silver, and then hammered or rolled or stamped into the required form." William Bell, of Birmingham, was granted a British patent in 1779. His specification states that "the rollers or cylinders for the purpose of making buckles and buttons are made of steel, iron or metal, and are engraved, sunk, or impressed with dies of buckles and buttons, which are confined opposite to each other in a frame, and are turned by a mill, or by hand, after the same method as those commonly used for the purpose of rolling or fluting gold, silver, iron or metal. The gold, silver, iron or metal to be made into buckles and buttons receives the impression of buckles and buttons by being conveyed between the rollers or cylinders."

It appears from this that, in Bell's time, metals were "rolled or fluted" (fluting could only have been done by grooved rolls), and that the operation was a common one and the machinery well known. At the period of Bell's invention rolls were well known, certainly for rolling copper and brass sheets, and the mills were open to the inspection of curious travelers.

In the diary of Dr. Samuel Johnson, relative to his tour in Monmouthshire and Wales in 1774, we find that he visited Holywell, and he states that "we there saw a brass work, where the *lapis culaminaris* is gathered, broken, washed from the earth and the lead,—though how the lead was separated I did not see,—then calcined, afterwards ground fine, and then mixed by fire with copper. We saw several strong fires with melting pots, but the construction of the fireplaces I did not learn. At a copper work, which receives its pigs of copper, I think, from Warrington, we saw a plate of copper put hot between steel rollers and spread thin. I know not whether the upper roller was set to a certain distance, as I suppose, or acted only by its weight. At an iron work I saw round bars formed by a notched hammer and anvil. There I saw a bar, of about half an inch or more square, cut with shears worked by water, and then beaten into a thinner bar. The hammers, worked, as they were, by water acting upon small bodies, moved very quickly, as quickly as by the hand. I then saw wire drawn, and gave a shilling."

All the operations and apparatus hereinbefore described here were in use prior to the date of the British patent issued to Henry Cort,—January 17, 1783,—which, as stated at the beginning of this article, has generally been regarded as embracing the invention of grooved rolls for rolling iron. Cort, himself, in his claims, placed no emphasis on the invention of the rolls themselves, but a great deal upon the method of "faggotting up" bars of iron and upon certain ways of making scrap piles.

MODERN PUMPING MACHINERY FOR MINE SERVICE

By Otto H. Mueller, Consulting Engineer, Budapest

THE proper drainage of a mine has always been a knotty question, and only the last few decades can show distinct progress towards a really practical solution of the problem. The early engines were exclusively overground ones, with rods hung down the shaft, working pumps situated at different levels. Each of these passed the water on to the one above besides dealing with that collected on its own level. These engines were of the beam type, without flywheels, and constituted the first adaptation of steam as a motive power. It was on them that Newcomen, Watt, Trevithick and Stephenson made their experiments and most important inventions. In a modified form, known as the Cornish engine, they attained fame and general use; in fact, for a long time they were the accepted standard for pumping engines, and to this day there are not a few of them either in actual use or standing in reserve.

This type of flywheelless overground engine has been still further developed of late by Messrs. Hathorn, Davey & Co., in Great Britain, though, on the other hand, it has in many cases been superseded by flywheel engines of various builds. A connecting link between the two types is formed by the engine invented by Kley, of Bonn, which is provided with crank and flywheel, but can work reciprocating as well as rotating, according to speed.

A common feature to all these engines lies in the long and heavy rods, with their complement of attached pumps, balance levers or hydraulic compensators. Both pumps and rods are built in a number of different designs, the latter alternating almost equally between the single and double system. In the second case the two sets of rods are made to balance each other through being connected by bell-crank levers.

A serious drawback connected with the use of these rods lies, however, in the extreme length and weight which it is necessary to give them; moreover, as the length precludes their working on any other than tensile strain, the designer is confronted with the alternative of either building his pumps single-acting, or of using dead-weights attached to the rods, in order to give the delivery stroke. In both cases the weight of the reciprocated masses becomes simply enormous, extreme vibrations at the change of stroke following as a matter of course. To this should be added the fact that the numerous breakages to which both rods and connections are subject generally do a tremendous amount of damage, and almost invariably involve a lengthy stoppage and subsequent drowning-out of the mine.

Their maximum speed was, moreover, very low, which meant enormous engines, with proportionate foundations and prime cost of the plant, besides often-recurring repairs in spite of careful supervision. Attempts were then made to reduce the size and to increase the economy of at least the overground part of the plant, which resulted in the use of an hydraulic cylinder which imparted the reciprocating movement to the rod, being, in its turn, driven by high-pressure water supplied by a smaller, quick-running engine.

In spite of their almost fabulous price, these engines held their ground for a

number of years, chiefly in consequence of the opinion generally entertained by miners of the period that it was only by erecting the engines overground that the mine could be considered secure from danger of drowning. This is true to a certain extent, as, in case of a sudden inrush of water, the mine may become temporarily drowned without stopping the engines, and when, through natural causes, the flow of water decreases, the engine can by degrees pump the mine clear. In many cases, however, this does not happen, either because the drowned pumps become damaged to such an extent that they are incapable of further work, or, as is more likely to happen, because they cannot increase the output to the degree required, owing to the above-mentioned absence of reserve in speed.

The actual security attained by the use of these engines amounts to very little, and it is no wonder that under these circumstances the last twenty or thirty years show an always increasing tendency towards the adoption of underground pumping engines. The use of these engines affords a free choice as a medium for driving them between steam, air, or water, with a further alternative offered by electric power. Air, water or electricity involve the use of a primary motor, which is, of necessity, placed on the surface. As a consequence, either of these three methods of transferring power mean greatly enhanced first cost of the plant, as compared with that where steam is used. It is owing to this consideration that the latter is taken in the great majority of cases. With regard to security of working, both air and water have an advantage over steam, though the latter has proved itself sufficiently reliable.

In designing an underground pumping plant, no matter what type of engine is fixed upon, the first requisite is to provide reserve. The easiest and most generally adopted method of attaining this is to duplicate the engine. This secures a far greater degree of safety in case of a sudden inbreak of water than is possible with any type of overground engine, and even with this duplication the cost of the underground plant will come considerably lower than that of the older system of pumps with long rods.

A still higher measure of security is attained by the use of low-lift or force pumps, coupled on to the engine and situated from about 13 to 32 feet under the same. These lift water to the main pumps, thus giving the latter a time reserve, as it is then possible, in case of a sudden inbreak of water, or of a longer stoppage for repairs, to allow the mine water to collect in the whole of the bottom workings before the engine room is flooded. This arrangement has the further advantage of reducing the suction lift of the main pumps to a minimum, if, indeed, it is not eliminated entirely. In either case the security from interruption is materially increased, besides admitting of the engine being forced to its utmost limit of speed.

A third factor of safety lies in duplicating the steam pipe in the shaft. This also has the recommendation of economy, since, as is well known, the loss of steam through condensation in these long pipes is quite appreciable. This loss can be reduced by decreasing the size of the pipe. It is found to pay in most cases to have one pipe dimensioned for every-day running, and a second, larger one, usually kept in reserve, for the increased amount of work expected in emergencies. It has finally been proved by experience that even a steam pumping engine is not necessarily put out of action by becoming submerged. It is true that this refers to direct-acting engines only, there being a number of cases on record of such having pumped themselves free, while flywheel engines have been stopped under similar circumstances, owing to the resistance opposed to its external moving parts,—crank, crosshead, flywheel, and others.

As regards economy of working, the underground steam engines are found to be far in advance of all other systems, this being the outcome of their quick-running capabilities in connection with slight frictional losses and small consumption of lubricating material. The greatest loss inherent to the use of this

system is the condensation in the steam pipes. This, however, is capable of material reduction by the proper proportioning of the pipe to the amount of steam passed, and also by the careful covering of the pipe. In any case, it is a good plan to put in a big separator at the bottom of the shaft and close up to the pump. The loss of pressure in these shaft lines is surprisingly small, a number of cases in practice showing pressures on the engine quite equal to that in the boiler. This is, no doubt, due to the weight of the steam column and to the accelerating effect of the particles of falling water suspended in the steam.

The engines formerly taken for underground work were flywheel and direct-acting, indiscriminately, with a leaning, in recent times, towards the latter. A large number of flywheel engines working in Germany and Austria-Hungary are fitted with governed valves, chiefly on the Riedler patents. This is especially the case with engines dealing with large quantities of water against heavy pressures, though, on the other hand, there are numerous examples of grouped automatic and of multiple beat ring valves.

For underground service the flywheel engines are in many respects at a disadvantage when compared to direct-acting ones. In the first place they occupy a good deal more room, especially in breadth, and require heavier foundations. As the cost of the engine room and the foundation is an appreciable part of the whole, the disadvantage becomes an important item

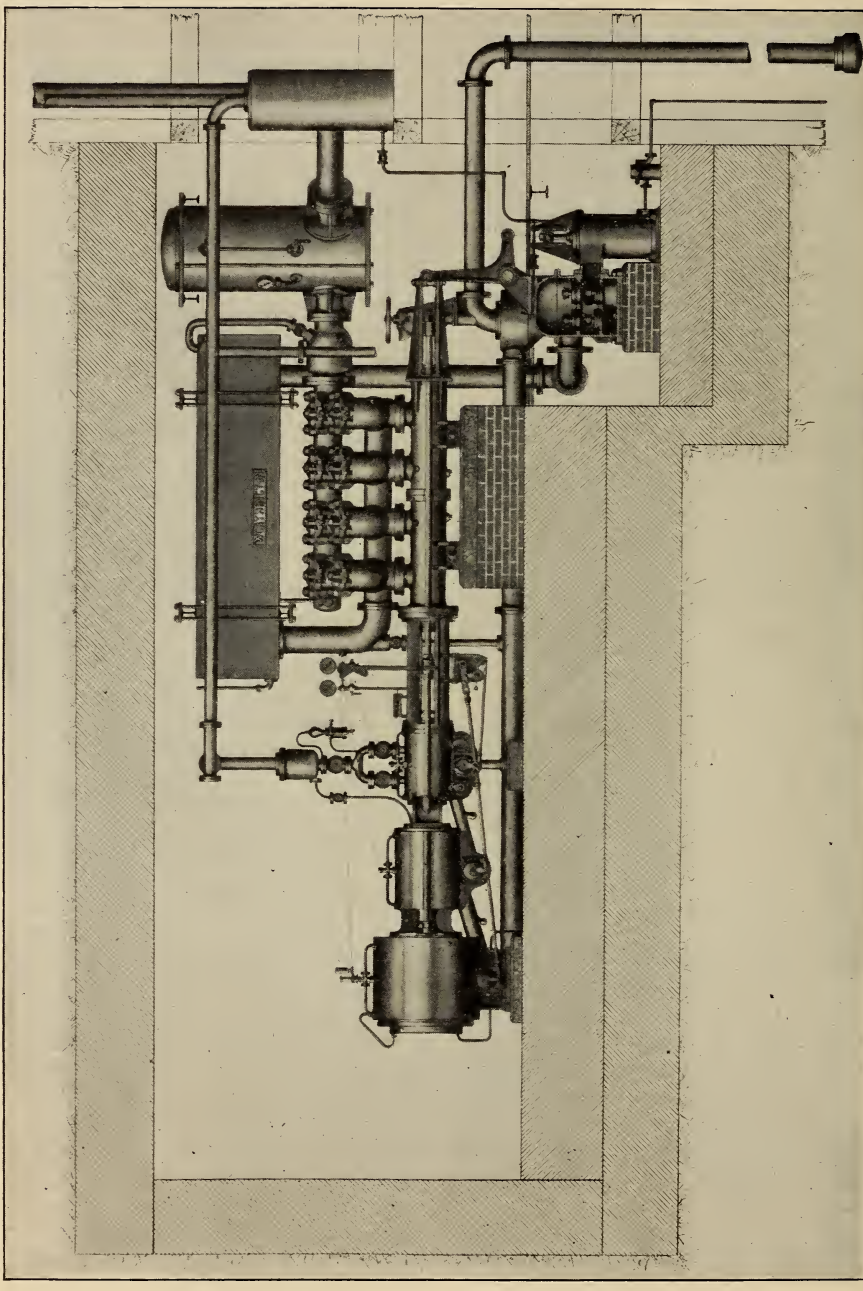
Secondly, the erection of such an engine is much more difficult, the girders and bedplates requiring accurate alignment, and the crankshaft careful bedding. Added to this is the necessity of splitting the engine up into small parts for lowering down the shaft, which means building many of the larger parts, such as flywheels, in sections. A third disadvantage comes from the danger of breakage through water in the steam cylinders, a factor which can be altogether neglected in the direct-acting engine.

Finally, if one take into consideration that the duplex engine can be fitted with much smaller air chambers (in many cases none at all), that they consume less oil, and are more easily under control as regards running, it will be found that they have the advantage on nearly every point.

Figs. 1 and 2 show such a duplex engine as built by the Worthington Pumping Engine Company. This is a triple-expansion engine, showing excellent results as regards economy. It is a very general, though mistaken, idea that the question of steam economy in an engine working down a coal mine is not of importance. One should not lose sight of the fact that a high consumption means more boiler power required, larger pipes and increased cost of insulation, besides the inconvenience of a higher temperature in the mine and of warmer water due to greater quantity of steam condensed. It cannot, therefore, be considered true economy to put down cheap and uneconomical machinery, as any saving on this count is soon eaten up by the enhanced cost of the accessories and fittings.

The low-lift pumps shown in the illustrations do service also as air pumps to the condenser. With this arrangement the water is drawn from the sump into the condenser by the vacuum; in other words, it is lifted up to the engine-room floor-level without any cost of power. By arranging the air pumps to deliver into a tank situated above the main pumps, as shown, the latter are always under pressure, *i. e.*, have no suction lift, which makes it impossible for them to draw air or to lose the water,—an important item in a pump which has to work against a high pressure, and especially in the case of a mine pump which has the disadvantage of having to deal with warm water, heated to a still greater degree in passing through the condenser.

As regards the design of the pump in question, this will be seen to contain a number of features desirable for the particular service, such as separate, interchangeable valve boxes, each valve accessible in itself through separate cover, and the latter fastened by swing



1.—A TRIPLE-EXPANSION MINE PUMPING ENGINE. BUILT BY THE WORTHINGTON PUMPING ENGINE CO., LONDON AND NEW YORK

bolts, which admit of a quick opening without removing the nuts. The engine illustrated is designed to lift 330 gallons per minute against a head of 1170 feet.

There is one contingency of special importance in the case of an underground engine,—the chance of a breakage of the rising main. As a means of obviating the danger connected with such an accident, the Worthington Pumping Engine Company use a device for loading the pumps in case of a sudden drop of pressure in the shaft by reducing the free area of the delivery to such an extent that the pump keeps its usual speed without racing, until shut down.

The apparatus consists of a plunger, loaded by weight or steam, which faces an opening of the delivery main leading from the pump. It is, of course, situated immediately behind the pump. As long as the working pressure is held in the main, the plunger remains at the top of its stroke, but as soon as the pressure drops beneath a certain point the plunger falls and tends to close the opening of the pipe. Fig. 3 shows such an apparatus, loaded by steam pressure.

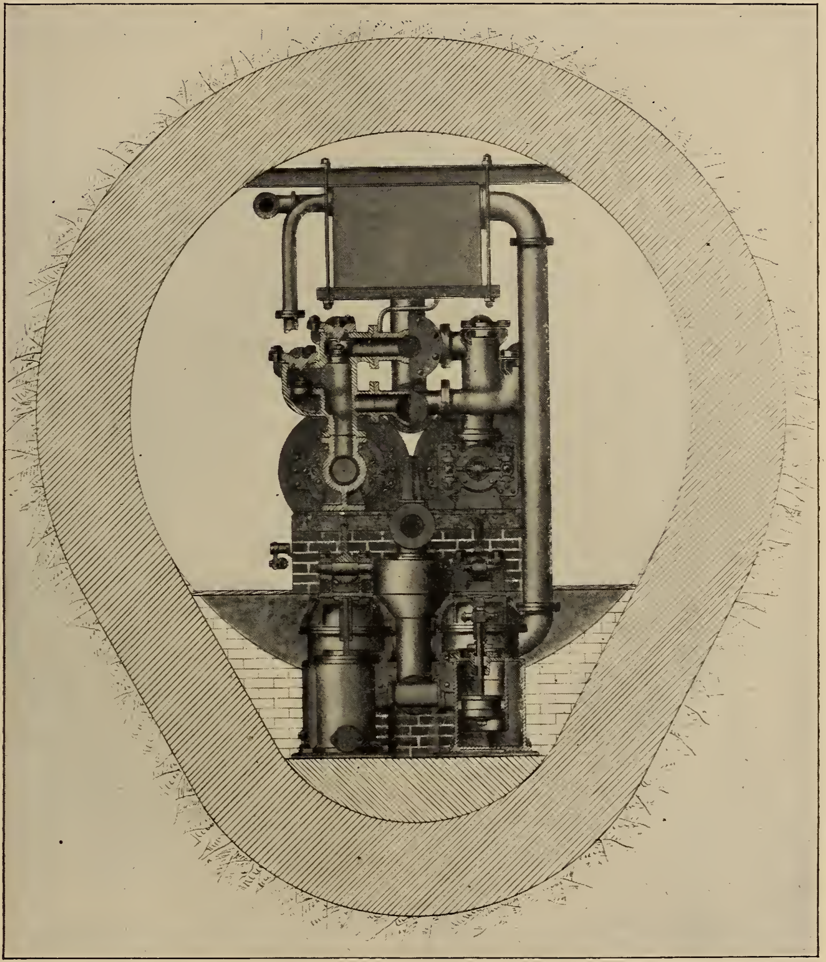


FIG. 2.—AN END ELEVATION

The pipe lines of a shaft require a great

deal of careful attention. They should be dimensioned as clearly as possible in order to reduce the weight and the volume of water contained. This holds good especially for the rising main, as, with the high pressures usually met with, the slight increase of friction may be neglected. The pipes should be well supported in sections, and should be provided with a corresponding number of compensating pieces.

There are many examples of underground engines arranged in stages, one above the other. This practice is, however, to be avoided as much as possible, involving as it does double the number of engine drivers otherwise required, besides making one engine dependent upon the other. The only case where such an arrangement is justified is when the larger portion of the water can be collected at a higher level and lifted from there direct to the surface. In this case the pumps of the lower levels should also lift to the surface, as it is not advisable to make one engine deliver to the other. The engines of the upper level do not, of course, require low-lift pumps or large collecting pumps for the water, as it is to be assumed that there is no danger of these becoming flooded.

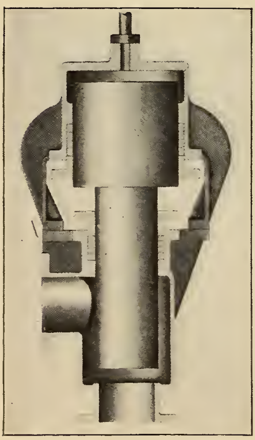


FIG. 3.—AUTOMATIC SAFETY DEVICE

An undeniable drawback to the use of the steam underground engines lies in the rise of temperature of the mine and shaft caused by the steam. In timbered shafts especially the wood is found to suffer through the heat, and, if the steam pipe is not thoroughly tight, through the escaping steam. In shafts liable to deformation, which is often the case with inclined ones, the steam pipes are found to give serious trouble and are difficult to keep tight. This applies also to the delivery main. In such cases it is advisable to employ electricity.

A badly insulated steam pipe will often disturb the ventilation of the mine. In a ventilating shaft, the carrying off of the gases will be assisted by the presence of the hot pipes, but as these are mostly laid in the winding shaft, which at the same time acts as a downtake for the fresh air, the influence of the steam pipe is generally a disturbing one. Careful insulation will, however, reduce this cause of complaint to a minimum, while in brick shafts with iron framing it scarcely comes into consideration.

The heat of the engine room, which is always built as small as possible, is also very unpleasant and necessitates the lagging of all hot parts of the machine. A good plan is to build a case quite around the steam cylinders, filling up the space with non-conducting material and leaving only the stuffing boxes and most necessary flanges free.

Long horizontal steam pipes are to be avoided in a mine. In case this should be impossible, it is best to employ compressed air as a motive power. Compressed air has the great advantage that after doing work in an engine it can be used to ventilate the mine. An offset to this good point, which renders its general use impossible, is its tendency to form ice, which cannot, in a mine, be counteracted by heating by fires, and secondly, by the practical difficulties which prohibit any working pressure above four atmospheres. At this pressure the loss through friction is extremely great, and the efficiency of the engines very low.

Another disadvantage lies in the explosions which will occur in the pressure pipes, occasioned by gases developed by the lubricating oil used in the compressor and the motor cylinder. These are in many cases dangerous and destructive. Compressed air has also the fault of being wasteful in power, besides requiring heavy primary outlay on the machinery. For big underground stations steam is at present in exclusive use, driving pumps which have capac-

ities up to 5000 gallons per minute against 1200 to 1500 feet, and there do not seem to be any indications at present of its being in danger of a compulsory retirement. On the other hand, no one can question the particular advantages which air offers as a medium

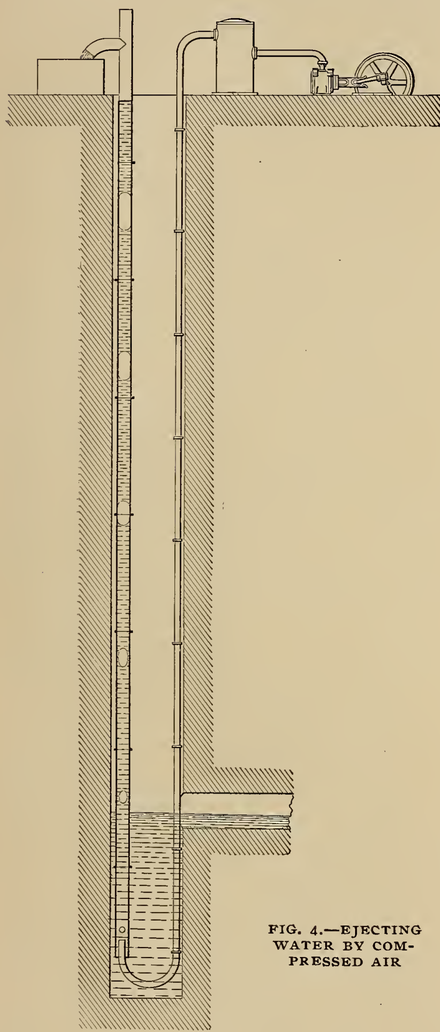


FIG. 4.—EJECTING WATER BY COMPRESSED AIR

for driving smaller sinking pumps, winches, or smaller pumping stations, located at different points of a mine.

Air is capable of being employed on any system of pumping plant as an auxiliary towards strengthening existing machinery. Suppose we have the case of an underground engine, designed to work against a certain pressure, and, by reason of the dimensions of either steam or water-end, incapable of working against a higher pressure, its owners, however, wishing to have it work on a lower level, *i. e.*, against the higher pressure. Any structural alterations on the pump or on the engine may be saved by reinforcing the machine with a compressor capable of lightening the water column by driving air into the delivery main, just behind the pump. The same method can be applied to the driven pumps of any overground engine, simply by attaching a compressor to each pump and causing it to blow air into the delivery pipe immediately above the pump.

It has been proposed to apply air for mining service in the shape of a Pohle apparatus. The principle of the latter consists, as is well known, in driving air from an overground compressor down a pipe which opens into a second pipe, which, in its turn, is immersed to a certain degree in the water to be lifted. The air, leaving the central pipe (Fig. 4), forms large bubbles, which expand as they rise, thereby elevating the water in the pipe to the point at which it can overflow.

The principle of lightening the water column, which, in the present case, is done without any pumps or valves whatever, is therefore the same as in the case mentioned previously; it is successfully applied for pumping from bore holes, which service supplies in an eminent degree the requirements of a deep-water reservoir, *i. e.*, a high water column to counterbalance that which is to be lifted and to impart the speed necessary for the lifting action. It is precisely this requirement which places the system at a disadvantage as far as application to mining service is concerned, necessitating, as it does, the splitting up of the total lift into stages, each provided with a separate apparatus, which would have to be fed from a central air supply pipe (Fig. 5). The result would naturally be very imperfect, as, in the first place, the efficiency of the apparatus is extremely low, in spite of the much-vaunted use of the expansion of the air,

while secondly, the increase in capacity is very small, and is attained by enormous expenditure of air. In a similar manner it is equally difficult, or impossible, to run the apparatus at a lessened

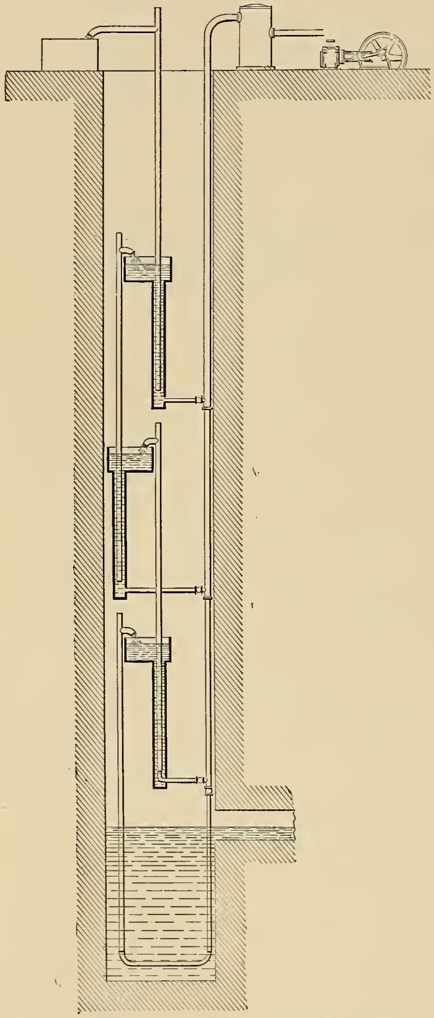


FIG. 5.—EJECTING WATER BY COMPRESSED AIR. A SERIES SYSTEM

rate. In face of these disadvantages, there seems little cause to expect a general application of the system for mining service.

Considerable attention has been paid, of late, to the means of utilising pressure water for transferring the power required for underground pumping engines

This method has been adopted with success in a number of cases for carrying power to a distance on the surface. The requirements for a mining plant are:—an overground pressure pump, a pipeline down the mine, and an underground pumping engine driven by pressure water. The latter may be returned, after doing its work, either by means of the delivery pipe of the pump, or by a separate return pipe. The latter is, undoubtedly, the better plan of the two, in view of the fact that the pressure water should be kept as clean as possible, which is never the case when it is mixed with the mine water. It has the further advantage of ensuring a better lubrication of the valves and other moving parts of the hydraulic motor, as, when the same water is used over and over again, which is the case when the return pipe is used, the water can be made to act as a lubricant by mixing some soluble grease, such as vaseline, with it. This requires renewing only at long intervals.

It will easily be seen that the use of this system means working with heavy water pressures, owing to the fact that it is only the difference between the water and the back pressure, which latter is equal to the height of the return column, which is available for work on the motor piston. If we take, for instance, a shaft 800 feet deep, with a difference in pressure in the motor cylinder of 400 pounds, the admission pressure of the motor cylinder will have to be 757 pounds, though the pressure pump will, of course, only have to deliver 400 pounds.

Many engineers are of the opinion that the efficiency of the underground engine increases in the same measure as the value of the back pressure decreases as compared with the total pressure. As a consequence, they carry the latter up to 3000 to 4000 pounds. Thereby they certainly attain the advantages of very small supply pipes for motors with a corresponding reduction of volume of contents, the effect of which masses might give rise to dangerous shocks.

On the other hand, this procedure is

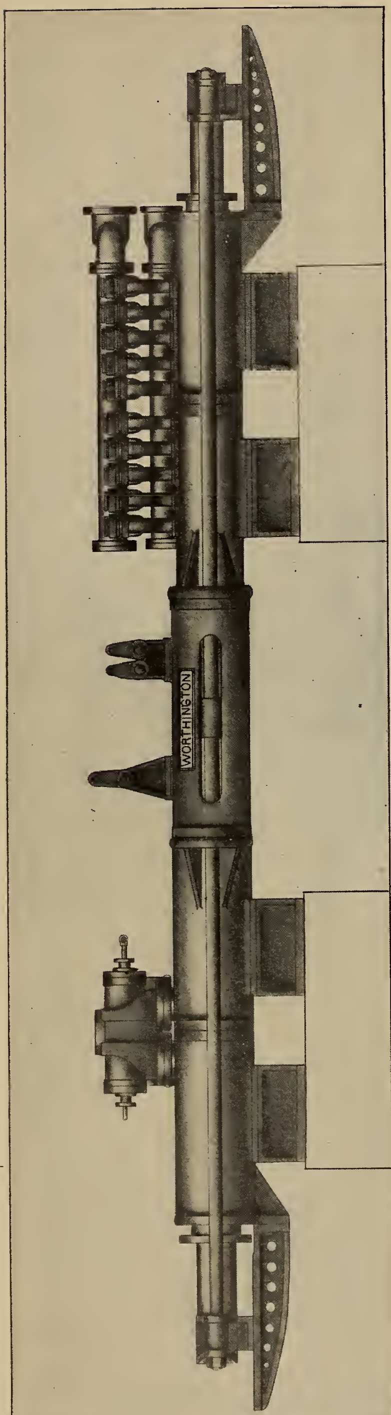


FIG. 6.—A WORTHINGTON HYDRAULIC MINE PUMP

open to serious objections. In the first place, these high differences of pressure make it extremely difficult to keep the distributing mechanism of the motor cylinders, chiefly pistons and slide-valves, tight. The advocates of the above ideas deny the existence of these faults. It is, however, a fact that they do exist; at any rate, the writer is not aware of any style of slide-valve hitherto constructed for which immunity from this trouble could be claimed for any length of time. It is also certain that such defects make a big hole in the efficiency claimed for, and, for a time, probably attained by, these plants. Any one knowing the cutting qualities of water at very high pressures, will admit the justice of these remarks.

Neither can it be claimed that the cost of the underground engine is reduced to any extent by adopting these high pressures. The pump end remains wholly unaltered; the motor end becomes certainly smaller, but proportionately more expensive owing to the necessity of using special materials, such as wrought iron, semi steel or gun metal, in order to stand the high pressures. Many designers of pumps do not care to take any higher difference in pressure than 800 pounds in the motor cylinder. For hydraulic power, the direct-acting engine has shown a marked superiority on all points. The original experiments were carried out on flywheel engines, both for the pressure-pump overground and for the underground pumping engine. As far as the latter is concerned, the flywheel type was very soon abandoned.

This is easy to understand, as the crank mechanism, with its variable speed and rapid reversing of the direction of movement, is not suited to the slow and constant movement of an hydraulic engine, although attempts were made to get over the difficulties by using two pumps in place of one, each with three cranks. The direct-acting engine shows a marked contrast. The swinging masses are almost entirely absent, the water cylinder and the pump act on each other with a sort of mutual give-and-take, the work being, as a result,

very smooth. Each side of the duplex engine finishes its stroke quietly and evenly at the exact time at which the other side commences its stroke. The movement of the water in the pipes is consequently very even. All friction of bearings, eccentrics, and other parts of the flywheel engine is entirely done away with, making the hydraulic duplex engine the nearest approach to perfection yet invented, both as regards smoothness of working, and efficiency.

The physical qualities of water make it imperative that the hydraulic engines run at as low a rate of speed as possible. This should in no case exceed 20 to 25 double strokes per minute. With a direct-acting pump this presents no difficulty, the valve area for a given quantity being quite independent of the number of revolutions at which the engine runs. The only parts dependent on this factor are the pistons, which must, of course, be made larger for the slow speed. The overground engine can, on the other hand, be designed for high speeds.

As regards the dimensions of the pipes for the pressure water, these may be fairly small, the pipe resistance and consequent losses in head being in any case negligible when compared to the high working pressures, besides being partly counterbalanced by the advantages due to the reduction of the volume of water.

It has been found necessary to use a pressure-compensating device in the pressure line between the primary pump and the motor underground. This is due to the fact that it is impossible to time the two machines to work synchronously; in fact, they are, as a rule, designed to work at widely different speeds. Dead-weight accumulators, which were tried, did not answer the purpose, owing to their inability to relieve the system from the water shocks which they were supposed to eliminate. The next step was the use of elastic air or steam accumulators, which can be conveniently built in, close to the top pressure pump.

As the most simple to handle, the steam accumulator possesses many recommendations. A good example of this type will be found in the one shown in Fig. 7. In this, the boiler steam, suitably reduced in pressure, effects the

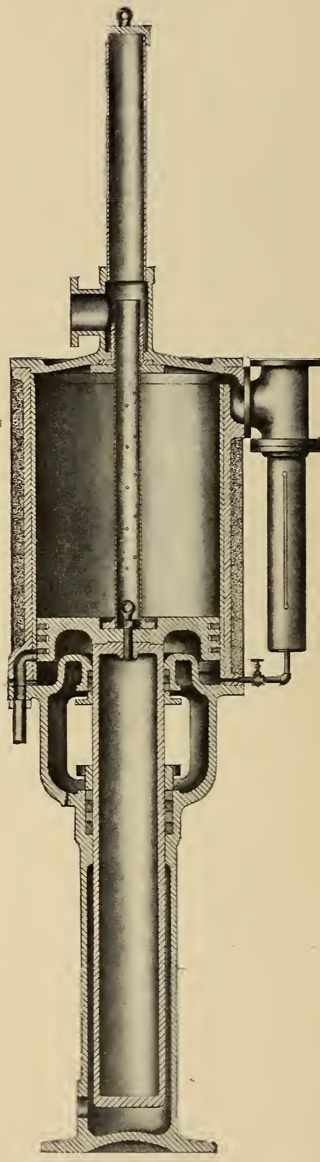


FIG. 7.—A STEAM ACCUMULATOR

loading of the water ram. Many engineers recommend an air accumulator before and behind the underground engine. With direct-acting engines this

is unnecessary; at any rate, the one before the engine may safely be left out, and in most cases the one behind also. For bigger plants it is certainly advisable to allow some method of compensation in the return pipe, but as the exhaust pressure is comparatively small, an air chamber will be found to answer the purpose. Direct-acting engines are now often employed for the overground work as well, as their use admits of a smaller accumulator and ensures a more even movement of the water in the pipes.

The hydraulic system of transmitting power, above described, has the important advantages of not heating the mine or disturbing the ventilation, nor is it detrimental to the shaft; the underground engine is further absolutely unaffected by being flooded. The degree of efficiency of a well-designed and well carried out plant is, further, found to be quite acceptable, — about 70 per cent. and over. The attention required also is slight. The plant is, however, rather costly in the first place, the price coming to certainly double that of an underground steam plant of corresponding size, though still it is some 30 per cent. cheaper than an overground engine with rods. The comparison with the latter becomes more favourable with the increase of depth. The security offered by the hydraulic plant is, moreover, considerably greater. It is in all probability this costliness which has acted against the more general use of the system.

As a further means of transmitting power, electricity has, of late, been applied in a number of cases. In common with the hydraulic system, this method has also the advantage, when compared with steam, of not heating the mine. It follows, as a matter of course, that it is well adapted for older mines which are liable to shift, for inclined shafts suffering from the same defect, or for distribution along the workings underground. In point of convenience, it surpasses all of its competitors, whether water, air or steam. It is especially advantageous in cases where electricity is used also for other purposes down the mine, such as lighting, winding or ventilating. If, in addition, electrical machines are used on the surface, for main winding, ventilating or coal-riddling machinery, that is to say, if one has a complete electrical central station, then, with all its disadvantages, it may pay to use electricity for pumping in the long run.

The ratio of the amount of power required for pumping to the whole amount used is of great importance. If electricity be used for pumping purposes alone, the plant will be very expensive and uneconomical, as it may be safely assumed that only in exceptional cases more than 50 per cent. of the whole indicated power used to generate the electricity overhead will be returned as useful work. A further difficulty is experienced in transferring the power from the electric motor to the pump, that is, in the gearing down. For this purpose belting, ropes, gear wheels and worms have, one and all, received exhaustive trials. Belts and ropes are found to be too short-lived in a mine. A worm and wheel affords the simplest arrangement, but is wasteful in power and oil, and is further subject to extreme wear and tear. Gear wheels give, on the whole, the best results.

In order to reduce the inequality of working as much as possible, the pumps are either constructed with three single-acting plungers with cranks at 120 degrees, or with two double-acting plungers with cranks at 90 degrees, or finally, with two differential plungers with cranks at 90 degrees. The first arrangement gives six sets of valves, three plunger stuffing boxes and a 3-throw crank. The second arrangement requires four plunger stuffing boxes and eight sets of valves, but gives the most uniform flow of water in the delivery and suction pipes. The third arrangement necessitates four sets of valves with four plunger stuffing boxes, and gives an even flow in the delivery, but requires suction air chambers. All these systems are expensive.

Electrical pumps are, of course, unable to work under water; in fact, the moisture contained in the atmosphere

of many mines is sufficient to make them liable to short circuit, which means stoppage of the pumps. They require considerable attention by skilled, and consequently expensive, drivers, and as a non-sparking dynamo is still to be invented, their presence in a mine carrying explosive gases is always attended with danger.

For the time being, steam holds its own as far as underground pumping service is concerned, more particularly in the case of big engines. Steam is further generally used in sinking service, on account of its cheapness, although compressed air would seem better suited for the work. For this service hydraulic transmission seems less adapted, electricity perhaps more so, though electric sinking pumps are invariably cumbersome and of big dimensions. It will not be out of place to refer briefly to the bucketing system of elevating mine water. This is never used for regular work, and is recurred to only for clearing a drowned shaft. The method of working consists of attaching iron dipping buckets, with valves in their bottoms, to the winding cages, or of running water cars into the cages themselves and dropping the whole into the water and hoisting it to the surface by the winding engine, whence the water is either run off, or, if tip cars are used, carried away by these. In some very narrow shafts this system of elevating the water is retained for regular work by hanging leather buckets on a rope. Another application of the system, which also admits of regular work, is to be found in the chain pump. But the heavy deadweight of the apparatus restricts its use to very light lifts—up to about 100 feet.

THE LAKE PASSENGER STEAMER "CITY OF ERIE"

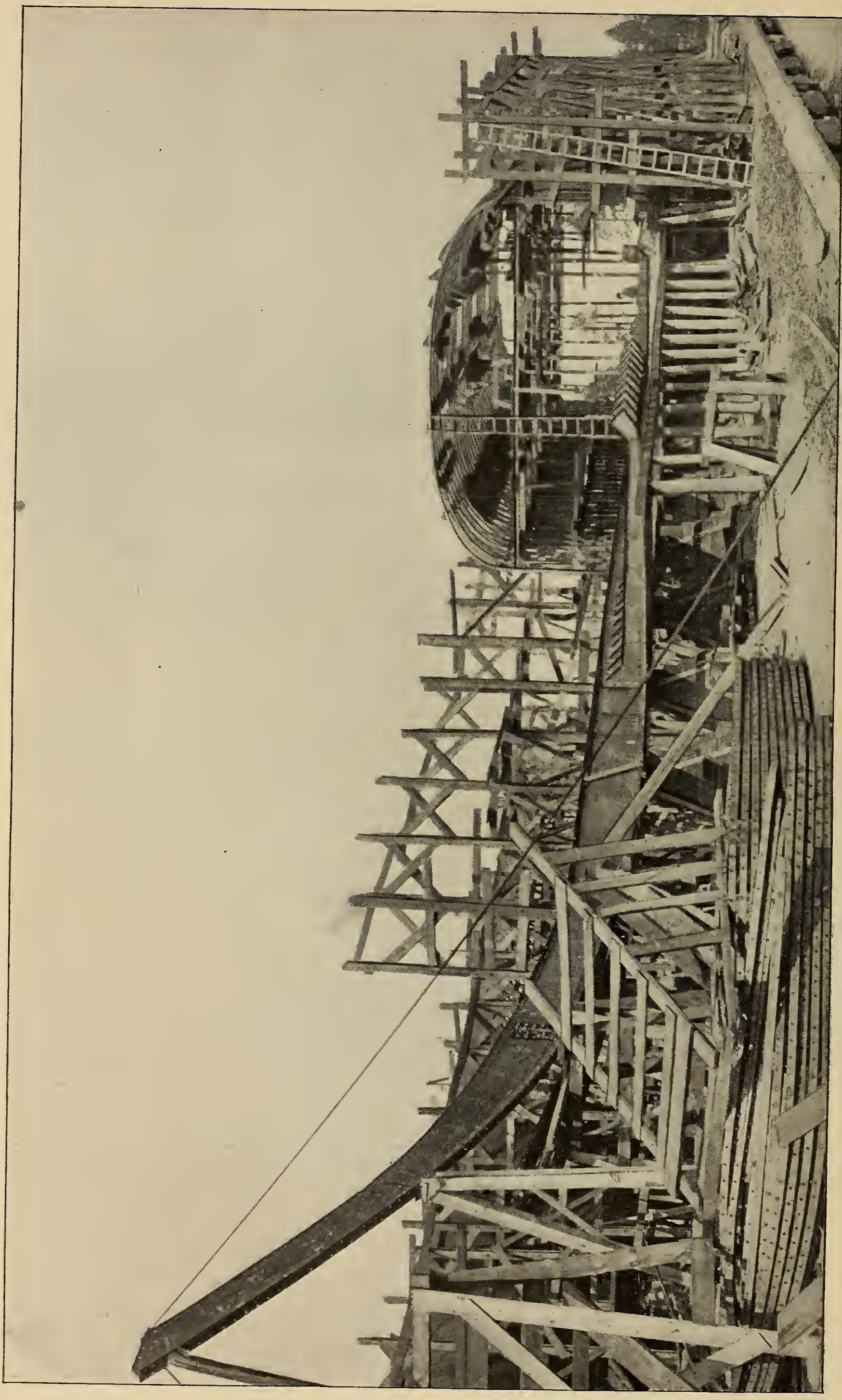
AMERICAN LAKE SHIPPING AND CASUALTIES

By George Ethelbert Walsh

THE hazard of life and property on the ocean is supposed to be so great at certain seasons of the year that underwriters find it a matter of business policy to mark up insurance rates to meet the extra risks. In the southern tropical seas during the hurricane season sailing vessels and ocean steamers are subjected to a fury of winds and waves that makes their existence decidedly uncertain, and every storm that develops in the tropics and sweeps across the lanes of ocean travel carries destruction to scores of ships and cargoes. In the North Atlantic when the fog banks hang heavy over Newfoundland's shoals, or when the tempestuous storms of winter lash the sea, the casualties to shipping multiply with alarming rapidity.

But while we expect rough usage to ships on the great salt seas, and shipping disasters are discounted beforehand by insurance companies, we have not, as a rule, been prepared to expect great disasters on inland bodies of water. The great rivers and inland waterways in the United States have always been vast arteries of travel, and the value of the commerce that floats up and down them is, in the aggregate, greater by far than that which is sent across the ocean. The rivers and canals are free from the mishaps that vessels on the sea must always be prepared to encounter, but on the Great Lakes navigation presents a different problem.

In the past half century marvelous developments have gone on apace in the great American Northwest. From Canada, the illimitable northwest country, and from the United States frontier an imperial commerce has been rising year by year into a mighty stream which sweeps irresistibly toward the Atlantic Ocean. A mercantile fleet has been built on the Great Lakes that



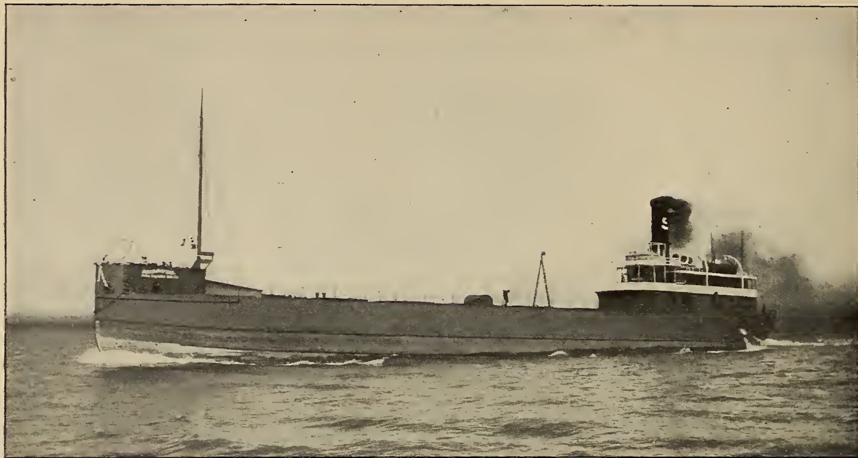
A WHALEBACK STEAMER SKELETON

rivals anything on either of the American coasts. While ship-building may have lagged and halted in modern times on the Atlantic seaboard, it has been alert and vigorous on these great inland waters. It has kept pace with the development of a new northwest empire, the resources of which are barely conceivable by those who are not intimately associated with it.

The evolution of ships on the Lakes has been as interesting as that of the vessels on the seaboard. Beginning with the Indian's canoe, which skirted the shores in early times, the evolution has included the small sloop and schooner that were such familiar sights a century ago off the New England coast, the large wooden brigs which succeeded them, the modern steel freighters of to day, and the magnificent passenger steamers that ply between the large ports. In building up the shipping commerce of the Lakes the designers of the vessels tried to produce boats with the greatest carrying capacity at the least outlay of funds. At first safety was sacrificed to cost. It was reasoned that the shipping of the Lakes would not be exposed to such violent elements as those prevailing on the ocean; but in time builders and owners realised their mistake.

Now that the great lanes of travel on the Lakes are filled with innumerable craft, every violent storm creates enormous damage, and the necessity of constructing practically ocean-going vessels for the Lake traffic is keenly realised. In the spring of 1898 forty-three ships were under way in the shipyards of Lake Superior, valued at \$5,350,000, ninety per cent. of which were practically ocean-going craft. Both insurance men and ship-builders are now figuring on the construction of vessels and steamers that will be even more seaworthy than those built in the past. Lake marine insurance has been, for years, chiefly in the hands of British

A WHALEBACK STEAMER IN THE SAULT STE. MARIE CANAL LOCK



THE STEAMER "ANDASTE" OF THE LAKE SUPERIOR IRON COMPANY

companies, and it is estimated that in the past four years they have come out with a loss, so general and extensive has the damage been to the shipping by storms.

Many strange and mysterious wrecks mark the history of Lake shipping, and the lives of hundreds of sailors have been snuffed out in a day and night. Vessels have disappeared on the Lakes as completely and mysteriously as on the ocean, leaving no trace behind them to indicate the nature of the tragedy. This sort of uncanny disappearance has long been supposed to belong exclusively to the ocean, where thousands of miles of water stretch out in all directions.

One of the earliest and most mysterious of the Lake tragedies happened back in the fifties when the Mormons, under King Strang, occupied Beaver Island. Those who may recall the events of those early days will remember what general excitement was created throughout the United States, not so much by the wreck of the brig *Robert Willis*, but by the published story that the Mormons had lured the vessel on Beaver Island, murdered its crew, and appropriated the cargo for their own use. This story, of course, was an unjust rumour, and was founded upon no definite facts; but for a time it created intense ill feeling toward the Mormons. The brig was last seen near the island, and then she disappeared completely from all human sight or knowledge. She was a sister ship with the *Fox* and *Lansing*, all three of which were built at Buffalo after special designs, which were supposed to make them peculiarly well-adapted to buffet the waves of the Lakes. She left Chicago for Buffalo with a load of flour and provisions just before the rivers froze up, and, running into a blizzard, she never again reached port.

Another strange mystery that hangs over the Lakes is the total disappearance of the schooner *J. B. Martin*, which left Milwaukee with a cargo of grain and was completely lost in a storm. These two old-time wooden ships never left any signs of their wreckage behind them, and their crews and cargoes disappeared as mysteriously as the ships. They served to emphasise the necessity of better ships for the Lakes, especially in the fall of the year when the sea was apt to be swept by violent blizzards.

When the so-called canalers, a type of vessel that was intended to navigate both the Lakes and the canals, came into existence, they proved rather dangerous craft in rough weather. They were long and narrow, with flat bottoms, and constructed so they could pass through the Welland Canal. To

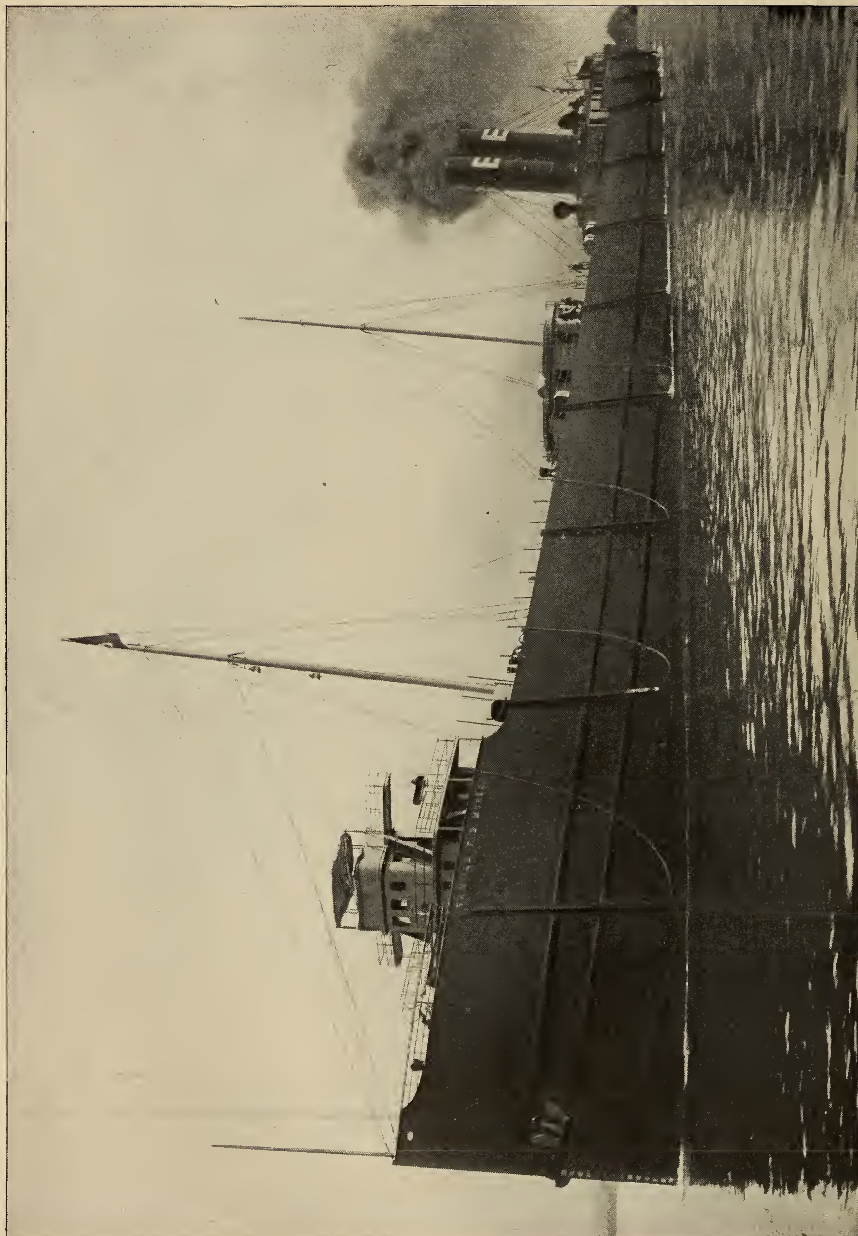
make their seaworthiness even more uncertain, it became the custom to load them a little deeper than the intended draught in order to save freight cost. The *Atlanta*, *Morrison*, and *Cornelius B. Windiate* belonged to this class of vessels. The first was an Oswego-built boat; she left Chicago with a load of wheat, and was never again heard from. Her mystery has forever remained unsolved; but it is supposed by Lake shippers that she was overloaded, and, running into a gale, she went to the bottom. The fate of the *Morrison* must have been the same. She left Chicago for Buffalo with a load of grain, but neither crew, cargo, nor ship ever turned up again.

The *Cornelius B. Windiate* was the largest of this class of canal schooners, and she was one of the strongest vessels of her type. But she sailed out of Milwaukee and totally disappeared from all human knowledge, and to-day she figures on the list of vessels that have never been accounted for. Probably all three of them lie somewhere under the shifting sands at the bottom of Lake Michigan or Huron, where many another ill-fated vessel is rotting.

The storms of the American Northwest are violent enough on land, but when one of the blizzards strikes across the Lakes it kicks up a sea that is not surpassed by any that heaves the restless bosom of the Atlantic. As a rule, navigation of the rivers and Lakes is precarious late in the fall, but the desire to get the last load through the rivers and canals before these are frozen up induces many shippers and captains to risk unseaworthy wooden vessels on the Lakes in the very teeth of storms.

The casualties on the Great Lakes have attracted special attention in recent years because the losses are heavy after every storm, although the accidents in proportion to the number of vessels in actual use are fewer than they were ten or fifteen years ago. One storm late last year was of unusual severity, and besides a score or more of old wooden vessels three of the finest ships ever launched on the Lakes were wrecked.

TOWING ORE SCHOONERS ON THE GREAT AMERICAN LAKES



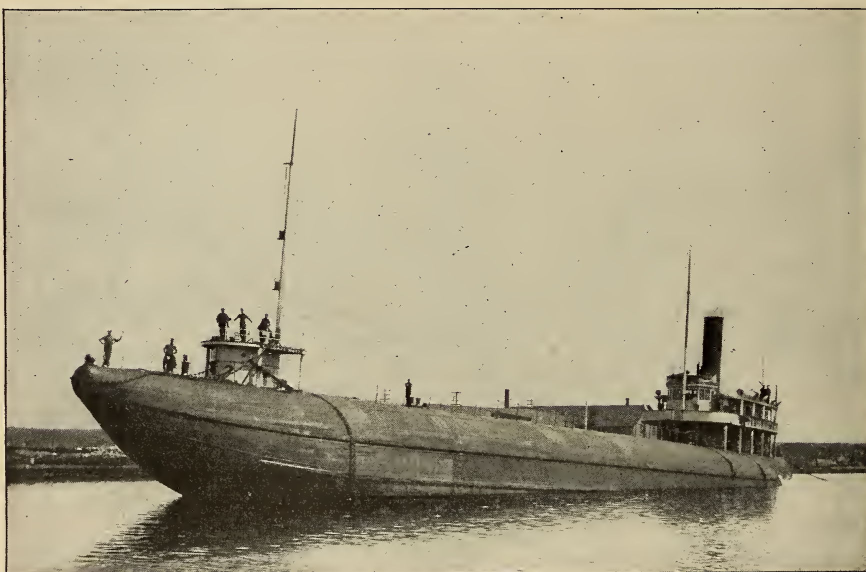
THE LAKE FREIGHTER "SAMUEL F. B. MORSE."

THE RESULTS OF A WINTRY TRIP

The loss of the three modern ships emphasised more than anything else the danger of navigation on the Lakes late in the season. It is no discredit to the builders of these steamers that they should have been wrecked on Lake Superior, for in many respects the sea in a blizzard runs as high there as on the Atlantic Ocean.

The modern steel ships of the Lakes weigh about 3000 to 3500 tons, and they carry from 4000 to 6000 tons. This would be called overloading on the Atlantic seaboard, and few owners would send their steamers across the ocean in this condition. The natural shallowness of the Lakes, in some places, adds to the risks of navigation. There are still many rocks which have not been located on any chart, and the steel freighter, loaded so deep, occasionally discovers them. No matter how softly she strikes, she is pretty sure to knock a hole in her bottom, and with her great load she sinks as swiftly as a stone. There have been many such losses in the past two years, and each wreck costs the insurance companies or owners a pretty penny.

The craze on the Atlantic Ocean to break flying records to Europe finds its counterpart on the Great Lakes in trying to break carrying records. Each new steel steamer built is known by its wonderful capacity for transporting enormous cargoes from one port to another. Thus the record for 1898 shows that each succeeding ship was built for the purpose of carrying a little more than the largest then in existence. Early in the year the steel freighter *Andrew Carnegie* broke the record by carrying a cargo of 230,000 bushels of corn, equal to 6440 tons. When the steamer *Linn* was launched, she carried a cargo of 6314 tons of ore, and later, 6496 tons of corn, just breaking the record established by the *Andrew Carnegie.* Following this steamer, the *Superior City* was launched, and she easily broke all records by carrying a cargo of 7563 tons of corn. This steamer holds the record for her class to-day. The steamer *Morse*, constructed after the *Superior City*, is 25 feet longer; but she has not yet attempted to lower the carrying record.



THE WHALEBACK STEAMER "COLGATE HOYT"

The same attempt to break carrying records is made by the owners of the wooden vessels. The schooner *John*

THE "SIR WILLIAM FAIRBAIRN"

A. Roebling holds the record for these ships. She carried on one load 7886 tons of ore, and her sister ship, the schooner *John Fritz*, carried 7795 tons of ore at one time. Prior to the launching of these two big vessels, the schooner *Australia* held the record of 6316 tons of wheat.

The immense carrying capacity of these vessels makes them valuable investments if no accident happens to them, but the system of overloading makes their powers of navigation a little uncertain in rough weather. Some of the steamers carry a whole elevator load of grain, and do the work with such dispatch that the cost was never before so low. The *Superior City* carried a load of 7562 tons of ore, and discharged it in twelve hours, breaking the Lake record for rapid unloading as well as for carrying the largest cargo.

These steel freighters are what is known as the 400-foot class, and they are the favourite ones on the Lakes to-day. They range from 400 to 475 feet in length, and they cost from $200,000 to $300,000; but they frequently carry cargoes valued at twice their own cost.

One of the remarkable changes in Lake shipping during the past year was the withdrawal of many of the ships rom services on the inland seas to the Atlantic seaboard. About fifty of the Lake ships, of all sizes and capacities, were taken to the ocean, and the drain on the Lake tonnage has been considerable. The fifty ships thus withdrawn were capable of carrying 3,000,000 tons of freight in a season. The demand for these ships was due partly to the war between the United States and Spain. Some of them are likely to be returned to the Lakes later, although many of them have become permanent fixtures on the ocean. The ship-building yards of the Lakes are rushed to their full capacity to make up for the loss thus experienced in the transference of ships to the ocean, and if there is to be a revival of American ship-building on the Atlantic coast in the near future, the same will be true of the Great Lakes. In fact, the revival set in some time ago, and the industry is steadily growing. A score of new ships, both wooden schooners and steel freighters and passenger steamers, will soon be ready for launching, and the frames will be laid for still others. At the present rate of increase in Lake shipping, the demand for ships will probably keep pace with any that may prevail on the oceans for the next decade.

AMERICA'S EXPORT TRADE

DEVELOPING FOREIGN TRADE BY SAMPLE WAREHOUSES

In view of the great increase in the export of manufactured products from the United States,—great enough to have aroused the attention of manufacturers in all important industrial centres of Europe,—special interest is attached to one of the latest measures adopted by American manufacturers to further develop this trade, namely, the institution of American sample warehouses in foreign countries. Mr. Search's article, which was prepared at the special request of the editor of this magazine, has, therefore, a timely bearing.

By Theodore C. Search, President of the National Association of Manufacturers of the United States

A MAGAZINE article imposes too narrow limits to permit the writer to cover the entire field of work of the National Association of Manufacturers of the United States. As a single department of this work which may be treated appropriately in this place and at this time, what has been done and what is contemplated in the extension of the foreign trade of American manufacturers by means of co-operative warehouses may be of very general interest.

Very early in the history of this association the establishment of warehouses in various parts of the world for the display of samples of American manufactured goods came up for consideration, as an eminently practical method for extending the foreign trade of the United States, and from the very beginning of active work of the association this has been one of the important departments. The idea in itself is not new. Many American export merchants maintain large sample rooms in various parts of the world, and hundreds of foreign importing houses maintain similar establishments for the benefit of their clients, whose goods they handle. Hardly a week passes without the appearance of some enterprise of this kind which contemplates the establishment of a sample warehouse and showroom in some foreign country under the auspices of some firm or individual.

The practical development of this idea, however, by an organisation of manufacturers, maintained wholly upon a national and public basis, without any interest in the financial results of such an enterprise, constitutes the novelty and originality of the work that the association has done in this direction. The writer has been informed that the Swedish General Export Association for some years successfully maintained sample warehouses in several countries, organised and operated somewhat upon the lines that have been followed by the National Association of Manufacturers; but with this single exception the writer is not aware that any other organisation has ever undertaken the practical application of the warehouse idea. To be sure, several European associations of manufacturers and merchants maintain sample warehouses for promoting export trade; but they are maintained in business centres at home, and depend upon the visits of the foreign buyer, while the plans which have been applied by the association here considered provide for the location of such warehouses in the market where the business is to be sought.

From the mere suggestion of a system of foreign warehouses to the actual point of the first establishment is a long step, and that it required two years of continuous and active work to bring the first warehouse to the point of actual operation is not in the least surprising. Plans have been worked out, not for temporary purposes nor for application in a single establishment, but with a view to adoption in many cases under varying conditions and for permanent and continuous enterprises. After near-

ly three years of experience in this line of work, and the establishment of a large warehouse upon a successful basis, meeting a variety of conditions which could hardly be encountered under any other circumstances, it is fair to assume that the results of this first undertaking may be regarded as indicating the practicability of the warehouse plan, and the feasibility of its application at points other than at that which was chosen for the first establishment.

The conclusion may be reached in a very few words. The sample warehouse established by the association at Caracas, Venezuela, has proved eminently successful, both in the actual results obtained and in the verification of the principles upon which its development has been based. Practical experience in the maintenance and operation of this warehouse has developed plans which, unquestionably, can be carried out in any important foreign business centre with satisfactory results that can be gauged only by the ability and energy of the management.

Frequent inquiries as to the reason for selecting Caracas as the starting-point in a system of warehouses has indicated how very little the manufacturers of the United States know about Venezuela,—its geography, its climate, its people and its trade. One reason for the selection of Caracas, although not a determining reason, was the possession by the association of a concession granted by the Venezuelan government, which extended to the organisation certain valuable privileges for certain enterprises. In a country whose tariffs are exceedingly high, and assessed upon gross weights of merchandise and packing, and where the absence of any bonded system necessitates the immediate payment of duties upon importations, the privilege of entering goods for a sample warehouse free of any duties is, in itself, a privilege of great importance to such an enterprise as that conducted by the association.

Of the South American countries, Venezuela is the nearest to, and most accessible from, the United States. It is also a land of great natural resources, whose coffee crop is mainly consumed in the United States. The city of Caracas, with a population of about 80,000 people, with not less than 20,000 more in the immediate neighbourhood, affords probably a larger market than any other city in South America. To these considerations must be added a universally prevailing sentiment of the most earnest and enthusiastic friendship for everything coming from, or relating to, the United States. No Spanish-American country is so strongly bound to the United States as is Venezuela, as may be quickly recognised by any one who visits that country.

It has often been pointed out that the association could have found much larger markets in South America in which to establish a warehouse. The search, however, was not for the largest market, but for one which offered the necessary conditions and at the same time sufficient business possibilities to warrant the undertaking. Investigation of business conditions in Venezuela has shown that there is not less than $5,000,000 of trade in articles which the United States could furnish, but which now goes to Great Britain and European countries. Any market which offers a possible trade for American manufacturers amounting to $5,000,000 or more per annum may safely be regarded as worthy of cultivation. These facts are sufficient to show why the city of Caracas was chosen as the starting-point of the warehouse system.

The association's warehouse is one of the largest and most imposing business buildings in the city, occupying a prominent location in the centre of the town, only two squares from the Plaza Bolivar, the beautiful park by which the Venezuelan honour the memory of their liberator. The building was erected many years ago by a wealthy Englishman as a private residence, and it must have been a magnificent home. Its interior arrangement, spacious rooms, beautiful stucco work and magnificent patio make it a striking edifice still, even when devoted to severely practical business purposes. It has a frontage of about 125 feet and

a depth of over 200 feet, with three large patios or courtyards.

The office of the warehouse, which occupies a large apartment, opening from the entrance passage, is a feature which attracts first attention from every visitor, for it is a model counting-room, in itself a complete exhibit of modern American office appliances. It is such an office as would attract attention from a business man in the United States, and in Venezuela, where such facilities and conveniences for transacting business are not known, the effect may well be imagined.

Around the sides of the patios a series of rooms of various sizes contain exhibits of samples of a great variety of articles manufactured in the United States, grouped in departments according to their character. In one room are the exhibits of pianos, organs and various musical instruments; in another are numerous lines of dry goods; hats and caps of felt, cloth and straw fill another; mill supplies form a department by themselves; and other departments are devoted to building materials, tools and hardware, plantation machinery, food products, undertakers' supplies, electrical goods, etc.

There are, in all, about one hundred exhibits, grouped in such manner as to be most convenient to the buyer who wishes to examine them. A very important feature of the warehouse is the library, which occupies a large room opening upon the main patio. This library, like the office, is equipped with the most improved American furniture, designed for this purpose and intended to show the people of Venezuela how a well-ordered library can be arranged. Files of all the leading trade papers from the United States are displayed in this room, and are available for reference purposes. These files are very much used by visitors, and are probably as much appreciated as any feature of the establishment. Such government publications as have any bearing upon the business interests of the United States are also on file in the library.

The whole purpose kept in view in arranging the warehouse was to make it a strictly business institution that should render the largest possible amount of service to the actual buyer and to the manufacturer whose goods are exhibited. It is not in any sense a mere passing exposition, but rather on the order of a salesroom of a large mercantile house. It is difficult to convey, either by description or by photograph, an adequate idea of the importance of this warehouse and the appreciation in which it is regarded by the people of Venezuela.

The formal opening of the house about a year ago was the great social and business event of the season in Caracas. President Andrade, who, ever since his first knowledge of the enterprise, has been unremitting in his encouragement of the project, attended the opening with his Cabinet and made the speech of the occasion. The audience gathered at that time was such as might befit any great public event in New York, and the genuine interest and enthusiasm manifested then and since could hardly find a parallel in any public affair in the United States. President Andrade has frequently visited the warehouse and spent much time there in a private study of the establishment, and nearly everybody of importance in business or diplomatic circles in Venezuela has since been an interested visitor there. As for the merchants of that country, they have come to recognise the warehouse as an important factor in the trade of the country,—as headquarters for everything American, as well as for many lines which have heretofore been sought in Europe.

It is interesting in connection with this to note the sentiments expressed by President Andrade in his address upon the occasion of the opening of the warehouse:—

"I believe that the National Association of Manufacturers of the United States will find among us something more than favourable markets; it comes to take a place at the Venezuelan hearth, and to give one more proof of the fraternity of the two peoples, destined to be friends, for the reason that both have the capacity to become great.

They, the United States, take the lead, and we aspire to follow in their triumphant march; we, as an incipient people, who understand the necessity of progress, they, constituted in potent democracy, that not only irradiates in America the pure federalism of their institutions, but that likewise illumines with the splendour of the furnaces in which are forged the works of civilisation.

"We, Venezuelans, owe a high debt of gratitude to the United States, and for this we open our markets to its sons, and our hearts that know and acknowledge kindnesses!"

The attentions that were shown to the committee of American manufacturers which attended the opening of the warehouse were marked by hospitality that was almost overwhelming. From the very beginning the association has had the most active aid and support from the government and the business interests of Venezuela, and there can be no question of the favour which the "Muestrario Americano," as the Caracas warehouse is known in Venezuela, holds among the people of that country.

The successive stages in the organisation of this enterprise have been watched with the deepest interest in Great Britain and Europe, and the history of the warehouse is probably as well known there as in the United States. By no one are the significance and importance of this movement so well appreciated and understood as by those who have hitherto chiefly controlled the import trade of Venezuela.

The primary purpose of the warehouse system which the National Association of Manufacturers has undertaken to develop is to make American manufactured products familiar to merchants in foreign countries by showing them samples and giving them all required information concerning the goods, their prices, weights, measures, manner of packing, and whatever else may be needed by the purchaser.

The sale of goods by the association in its warehouse has never been contemplated, nor is it likely to be ever undertaken. It is not the function of the association to buy or sell any merchandise; its aim is to bring buyer and seller together, and to offer to both all possible facilities for transacting business. It is but a very short step, however, from the showing of samples to the selling of the goods, and in the conduct of the Caracas warehouse a great many orders have been handed to the manager by purchasers who desired to have them forwarded to the manufacturers whose goods they had seen. In many cases this resulted in the establishment of direct dealing between the manufacturer and the merchants without the intervention of any intermediate agent, while in other cases the business has been passed through commission houses in the United States, sometimes at the preference of the buyer, and in other cases at the stipulation of the seller.

It is not intended that the warehouse shall occupy the position of a competitor with the importing merchants of Venezuela, or the export houses of the United States, and that this position has been successfully maintained is demonstrated by the very cordial relations which have existed between the warehouse and all classes of business interests with which it has been brought in contact.

The business of the Caracas warehouse, however, has developed to such a point that it has become necessary to make some definite provision for the handling of orders which result from the exhibition of samples and the furnishing of information. To meet this requirement, a selling department is now being organised for the purpose of conducting the commercial end of the business. This department will be a separate and distinct organisation in which the association will have no financial interest, but will dictate and control the policy of the department.

As the result of nearly three years of experience, the Caracas warehouse has developed a plan which can be applied with equally good results in many of the important markets of the world, and in the near future the association will

have at least one more warehouse on this system in active operation.

During the past three years the warehouse possibilities of many different cities have been carefully investigated and considered from every point of view, and negotiations touching at least two points have been in progress for many months past. It is possible now to continue the extension of this system, and it is difficult to form any estimate of the tremendous results that may be expected to come from the operations of an extended series of such establishments as that now in successful operation at Caracas.

One result of the warehouse there which gives some indication of what may be expected to occur in other similar establishments, is development of business in unexpected lines. Experience has proved that it is exceedingly difficult to predict what goods will prove to be saleable. It is customary to estimate the possibilities of any market by the goods that are being sold there, but in Venezuela it was found that many lines wholly unknown in that country have found a ready market when displayed there.

The work of the National Association of Manufacturers has been kept within strictly practical lines, and every effort has been directed towards the accomplishment of results that can be considered as having some business value. Probably nothing that has been undertaken by the association has been so far-reaching and so pronounced in its practical results as the warehouse here considered, and the extension of the system to cover a number of important centres in different countries will give to American manufacturers the most powerful agency for the extension of their foreign trade that has ever been placed within their hands.

THE LATE JEREMIAH HEAD

A BIOGRAPHICAL SKETCH

IN Jeremiah Head, who died early last month, the engineering profession has lost one of those members who, in a quiet, but enduring, manner carve out for themselves careers of distinction and usefulness. There are men whose life-work is not marked by anything of scintillating brilliancy, perhaps, but who accomplish with thoroughness and eminent success whatever task they may undertake, and to this class Mr. Head belonged,—careful and conscientious in the varied engineering duties which fell to his lot on both sides of the Atlantic. In the United States he was probably best known through his connection with the Otis Steel Company as consulting engineer, and one of the results of his latest visit to America last summer was a comprehensive paper, prepared jointly with his son, Mr. A. P. Head, on the Lake Superior iron ore mines and their influence on the production of iron and steel. This was presented about two months ago to the Institution of Civil Engineers of Great Britain.

As told in an earlier issue of this magazine, in which also a portrait of Mr. Head was published, he was articled, at an early age, to Robert Stephenson, the celebrated engineer, and served his time at the well-known locomotive and marine-engine building works at Newcastle-on-Tyne, England, carried on by his employer and others. Later, he was promoted to a position on his civil engineering staff. In 1856 he was entrusted with the design, and supervised the construction, of a large pair of compound condensing engines for driving the Priestgate Woollen Mills at Darlington, belonging to the firm of Henry Pease & Co.

A little later he was appointed resident engineer for the rebuilding of the iron bridge over the Wear at Sunder-

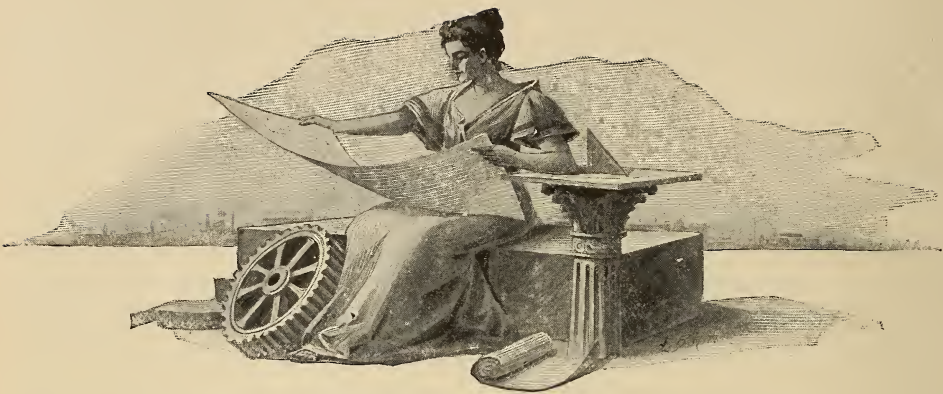
land, which occupied two years, and was Stephenson's last public work of any magnitude. He was then selected to co-operate with Mr. John Fowler, the well-known agricultural engineer, in bringing to perfection the steam plough with which that gentleman's name will always be associated, and in commencing the extensive works at Leeds, which became the principal seat of manufacture of them. The set of steam-ploughing apparatus which succeeded in gaining the much-coveted prize of £500 offered by the Royal Agricultural Society, and which was exhibited at the Chester Show in 1858, was mainly constructed at the Newcastle works, to the designs and under the supervision of Mr. Head.

In the year 1863, in conjunction with Mr. Theodore Fox, J. P., Mr. Head built large iron works at Middlesbrough, and carried them on until 1885, soon after which year they sold them, and dissolved partnership. Subsequently, Mr. Head, although still deeply interested in the Cleveland iron and steel industries, devoted his time and personal energies almost exclusively to professional engineering. He designed and supervised the carrying out of several iron and steel works plants, engines and boilers of considerable power and high efficiency, and coke and gas-making plants, and other installations. He made numerous investigations, sometimes under an order of court, sometimes at the instance of private owners, into properties in litigation or otherwise in difficulties, and his reports generally had the effect of indicating clearly the best course to pursue in order once again to reach smooth water.

He visited most European countries, more particularly Spain, Norway and Sweden, as well as the United States, and he made exhaustive reports on various properties, more especially iron, coal and manganese mines, and iron and steel works for English and foreign clients. He was frequently retained as technical expert in law and arbitration cases connected with mechanical engineering and metallurgy, but still more often as sole arbitrator. In one of these cases he was agreed on mutally between the War Office and one of their contractors, and after a long investigation succeeded in settling all the points in dispute. In other cases he was agreed to on both sides as referee for the settlement of wages questions between large employers and their workmen. Here, also, he always succeeded in arriving at decisions which secured the respect of both parties. As a valuer of technical and other properties Mr. Head had large experience, the aggregate amount of what passed through his hands in this way during the last few years reaching several millions of pounds.

As an author of scientific papers Mr. Head was well known. He contributed valuable memoirs and addresses to the British Association, the Institution of Mechanical Engineers, the Iron and Steel Institute, the Cleveland Institute of Engineers, the Sheffield Technical School and various other societies, as well as numerous leading and other articles to the current technical literature of the day.

In 1875 he was made a member of the Institution of Civil Engineers, and shortly after, a Fellow of the Chemical Society. In the year 1885, having long been a Member of Council, he was elected to the presidential chair of the Institution of Mechanical Engineers, and held that position for two years. In 1894, at the Nottingham meeting, he presided over Section G (Mechanical Science) of the British Association for the Advancement of Science. He was the originator in 1864 of the Cleveland Institution of Engineers, a society which has had a marked effect in making Middlesbrough the recognised centre of the British iron and steel industries. He occupied the position of honourary secretary for three, and of president also for three years. He was one of the original members of the Iron and Steel Institute; the treasurer and a member of the Board of Management of the British Iron Trade Association; and the same with regard to the Board of Conciliation and Arbitration of the North of England Manufactured Iron Trade.



Current Topics

DOUBLE BARREL guns have long been among the accepted types of sporting weapons, and multi-barrel pistols, too, of the so-called pepper-box design of a generation ago, are familiar, even to-day, to a great number of people. We have become acquainted also with the multi-charge cannon of more recent date, in which powder chambers were arranged along the line of a single gun-tube, intended to add the impetus of their explosive charges successively to the projectile as it passed along the barrel But a double-barrel cannon is something to which, one might say, antiquity has lent the grace of novelty. A cannon of this kind, probably the only one in the world,—a relic of the American Civil War of thirty odd years ago,—is one of the ornaments of the town hall lawn at Athens, Ga. In using this curious weapon the intention was to attach the ends of a chain, 50 feet, or thereabouts, in length, to two cannon balls which formed the charge, and the idea was that when these projectiles left the cannon, they would diverge, draw the chain taut, and, in their course, cut a wide swath through whatever was in front of them. The cannon, we are told, was taken out into the country one day to test it. When it was fired, however, one of the cannon-balls got a slight start over the other, and the result was disastrous, the projectiles and chain taking a whirling motion, ploughing up the ground all around and scattering the assembled spectators in every direction. That seems to have been the one and only occasion on which the gun was fired with anything besides simple powder charges. For saluting purposes the cannon was used a few times in after years, and when, not long ago, it turned up in a junkshop, it was purchased by the city of Athens to serve hereafter for purely decorative purposes.

IN matters electrical nothing has attracted quite so much attention within the past two months as the Nernst electric light, which may be said to have been introduced to the public by Mr. James Swinburne in a paper recently read at London before the Society of Arts. Briefly put, the Nernst light, so named after its inventor, Professor Walther Nernst, of the University of Göttingen, is an incandescence lamp without the usual vacuum bulb, and with the conventional familiar filament replaced by a rod of refractory material, —an insulator when cold, but a conductor of electricity when heated. This rod is mounted on two platinum wires,

—a little paste, made of refractory oxides, being applied to the joints,— and is mounted in a holder which fits ordinary electric light fittings. When the rod is worn out, a new one, with its wire mounts, is all that is replaced; the whole lamp is not thrown away. It is to be noted, however, that the Nernst lamp will not light up of itself, the rod, as stated, being an insulator when cold. The simplest way to start it is to warm it up with a match, or, better, with a small spirit lamp. The principal points made in favour of the new light are cheapness in first cost, lower cost of maintenance, and general efficiency, besides possibilities in the way of general economy in current distribution due to the permissible use of high voltages. To what extent all this will be realised of course remains to be seen. For the present we must content ourselves with the fact that, while the light is not yet by any means a commercial success, it is also far from being only the impractical scheme of an inventor.

One form of trouble with overhead electric power transmission lines for which the genus small boy was found to be responsible, developed several times within the past half-year in connection with the line supplying current from Niagara Falls to Buffalo. Short circuits occurred which compelled shutting off the power for periods ranging from several minutes to several hours, with more or less annoying accompaniments, and the underlying cause of them all was, for some time, a matter of perplexed speculation. Eventually, the explanation, as pieced together, took this shape. Several months ago a guard wire broke and one end, falling over the line wires, made an intermittent cross as it swung with the wind, producing an arc between two parallel wires, with attendant fireworks display of fascinating kind to a number of boys who saw it and who wanted to see more. Pieces of wire, barrel hoops and the like, thrown over the wires, afforded ready means of prolonging the fun, and while the arcs generally would break before much damage was done to the lines, the performance was hard on the switches and circuit breakers. With the cause of the mischief discovered, watchful patrolling of the line was instituted to prevent any further similar pranks, and arrangements were made at the power house end by which a short-circuit connection could be burned ofl by a lower potential current without danger of establishing an arc that might be maintained across the gap between the line wires.

There is something very suggestive in the statement recently made in the *Moniteur Officiel du Commerce* by a correspondent, writing from Suez, that work was commenced not long ago on two great oil tanks at Port Thewfik. These tanks are intended to supply fuel oil to steamships, and the company which is erecting them is planning the installation of a series of such "oiling stations" running to the Far East. Application is said to have been made to the Suez Canal Company for the privilege of erecting two 5000-ton tanks at Port Said, as well as at Port Thewfik. Land has been secured for tanks of a similar character in Borneo, at a spot only about 200 miles distant from petroleum deposits sufficiently large to supply fuel to all the ships going to the Far East for many years to come. Eleven reservoir depots have been established between Borneo and Suez, the equipment for them having recently been sent through the canal on two large steamers belonging to the oil company. With the proposed system the supplying of fuel to vessels will be a simple enough process; the boats will tie up to a wharf upon which will be hydrants connected with the tanks of petroleum, and all that will be necessary to replenish the vessels' fuel supply will be the turning of a spigot.

Apropos of the use of oil fuel for boilers, either afloat or ashore, a few

simple precautions must be observed in starting and stopping the atomisers by which the oil is sprayed. In a recent comprehensive article on the whole subject of oil-burning in *The Locomotive*, that instructive little organ of the Hartford Steam Boiler Inspection and Insurance Company, it is explained that the proper way to start these atomisers is to light a handful of oil-saturated waste, and place it in the furnace, before the sprinkler. The steam valve of the sprinkler is then opened, and the oil valve is opened last. In stopping the atomiser this course is reversed, and the oil valve is closed first. If these simple directions are followed, there should be no danger in starting or stopping the fires; but if they are not observed, the fireman, in all probability, will, sooner or later, be badly burned. If oil finds its way into the furnace without being ignited at once, it vapourises and its vapours mingle with the air, forming an explosive mixture that requires only a spark to produce the most serious consequences. Even when the atomisers are in full operation, they should be carefully watched, because they are liable, from time to time, to "snap out,"—that is, to go out suddenly, without warning. This anomalous behaviour appears to be due to the presence of water, either in the oil supply, or in the steam. The liability of the fire "snapping out" is much diminished by providing a settling tank on the oil pipe, where the water can sink to the bottom, and a similar chamber, or trap, on the steam pipe, so that entrained water may be caught and drawn off from time to time. Firemen, after working with oil atomisers for a time, are very likely to grow careless with them, and every now and then a fireman pays, with his life, the penalty for such carelessness. For example, when a jet "snaps out," the proper thing to do is to shut off the oil as quickly as possible, and allow the furnace to ventilate itself until there is no doubt about its being free from oil vapours. A piece of burning waste is then cautiously introduced into the furnace, just as in starting up, and the sprinkler is again set in action by opening the steam valve first, and then the oil valve. This routine soon becomes irksome to a thoughtless fireman, and he is apt to let the oil run, trusting that the highly-heated surrounding surfaces against which it strikes will speedily ignite it again. This, indeed, it usually does; but ignition in this way is uncertain, and the fireman who is not prepared for an immediate trip to that mysterious country from whose bourne no traveler returns, had better not rely upon it. He had better take a little trouble and do the thing right.

THAT a great railway company is called upon to expend annually immense sums of money for what seem to be comparatively trifling details of its business was forcibly illustrated recently by Dr. Charles B. Dudley, chief chemist of the Pennsylvania Railroad, in a lecture at Purdue University. He said that the purchasing agent of the Pennsylvania Railroad spends from $17,000,000 to $20,000,000 a year, and of that amount about $5000 goes for rubber bands, $7000 for lead pencils, $1000 for pins, $5000 for ink, $2000 for toilet soap, $1,000,000 for lumber, and $60,000 for hose. Attention was also called to the very interesting fact that it costs nearly as much for stationery with which to carry on the business of the road as it does for iron.